Marketing Research Report No. 387

a small country elevator for merchandising grain

Designs and Recommendations

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
TRANSPORTATION AND FACILITIES RESEARCH DIVISION
IN COOPERATION WITH:
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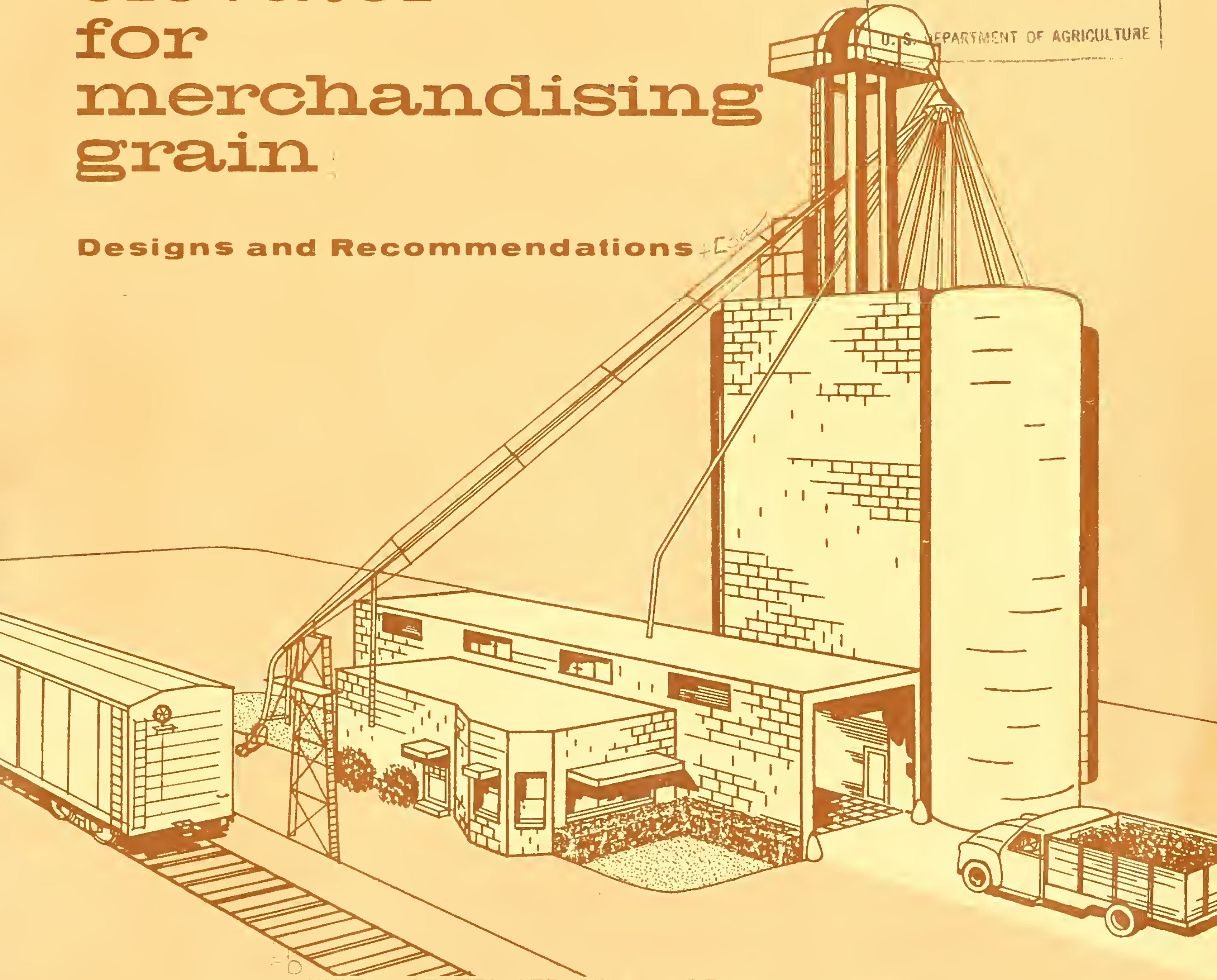

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PREFACE

This report on the design of small country elevators is part of a broad research project covering improved designs of commercial grain storage facilities. This research was conducted in cooperation with the Georgia College of Agriculture Experiment Stations.

The work was under the supervision of Leo E. Holman, agricultural engineer, Transportation and Facilities Research Division, Agricultural Marketing Service, Washington, D.C.

Many grain storage operators made their facilities available for this study. Also, designers and builders of grain elevators, and insurance agencies, offered many helpful suggestions and criticisms.

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A SMALL COUNTRY ELEVATOR FOR MERCHANDISING GRAIN:

DESIGNS AND RECOMMENDATIONS

by

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SUMMARY

The grain elevator operator can save money if, when building a new grain elevator or expanding his existing one, he makes sound decisions on such important factors as:

1. Selection of the building site. Careful consideration should be given to transportation facilities, utilities, bearing capacity of soil, and topography of the building site.
2. Layout of the plant. Basic principles of good layout should be used to integrate men, materials, and equipment so as to move grain at the lowest cost in a safe manner and under good working conditions.
3. Selection of building materials and construction methods which not only minimize construction costs but also depreciation, maintenance, insurance, and other annual costs.
4. Arrangement and selection of handling equipment to eliminate bottlenecks and reduce waiting lines.
5. Selection of necessary equipment, such as aeration systems, for keeping grain in good condition.
6. The design of buildings and equipment to minimize dust, safety, and fire hazards.

The above factors were considered in developing the improved plant designs illustrated in this report. The various plant components have been grouped together into five functional divisions or units as follows: (1) Storage unit; (2) receiving unit; (3) office unit; (4) corn shelling unit; and (5) grain drying unit. The improved plant designs are made up of various combinations of these units.

Four types of storage tanks are considered: Bolted steel, welded steel, concrete stave, and cast-in-place concrete tanks. Based on construction costs for the first quarter of 1959 for the Atlanta, Ga., area, the estimated construction costs per bushel for storage tanks of about 8,000-bushel capacity are as follows: Bolted steel—58 cents; welded steel—60 cents; concrete stave—65 cents; and cast-in-place concrete—70 cents. The welded steel tank design is suitable for construction by small local steel fabricators. Although the cast-in-place concrete tank has the highest initial construction cost, many operators find that it has the lowest annual facility cost (depreciation, interest, maintenance, and taxes).

Designs were developed for a country elevator having a storage capacity of about 32,000 bushels but receiving about 320,000 bushels annually. Three different types of elevators are illustrated in this report: (1) A plant handling shelled corn and small grain; (2) a plant handling ear corn, shelled corn, and small grain; and (3) a plant handling mainly ear corn. The plant designs are particularly suitable for the Southeast, or locations having the same needs.

A recommended design—the most completely developed design in the report—for an elevator receiving shelled corn and small grain has storage tanks of cast-in-place reinforced concrete and office building and drive shelter of concrete block construction. The grain is handled by two bucket elevators with a combined capacity of 4,000 bushels per hour. The estimated construction cost for the plant for the first quarter of 1959 was $96,000. The estimated annual facility cost—depreciation, interest, insurance, maintenance, and taxes—is about $8,400.

This recommended design has these advantages: (1) Maximum use of gravity flow; (2) a minimum of handling equipment; (3) most operations easily observed and supervised from the office; (4) storage tanks can be added in three directions for future expansion; (5) two elevator legs for flexibility of operations; and (6) a compact arrangement adaptable for one-man operation except possibly during the peak seasons.

Background of Study

The number of acres of grain planted and average production of grain per acre have steadily increased in the Southeast, with corn and oats showing the greatest increases. Soybean production almost doubled in South Carolina from 1952 through 1957 and showed marked increases in the entire Southeast also. This increased production of grain makes the shortage of good available commercial storage more acute and points up the need for additional handling and storage facilities.

Numerous requests are received for information on the design and construction of small county elevators. Not much information of this type was available; also, what information was available was not applicable to the Southeast. Studies on grain elevator operations and requirements were needed to provide a basis for developing improved designs that will be truly applicable to specific areas where additional commercial facilities are most needed.

Method of Study

Available literature on the production of grain in the Southeastern area was reviewed and the important grain producing areas determined. Interviews were held with personnel from State departments of agriculture, State experiment stations, and other government agencies in the Southeast to get assistance in selecting areas for study.

Areas for study were selected on the basis of the kinds and amounts of grain produced and the grain handling and storage facilities available in the area. Areas in Georgia, North Carolina, and Mississippi were selected for the study of existing plants.[1] Plants studied in Georgia were mostly in the southern part of the State in the heavier corn producing area. Those in North Carolina were in the heavy corn and soybean producing areas in the northeastern part of the State. The Mississippi Delta area was selected because small plants handling a number of different kinds of grain were available in that area.

Newer plants ranging in capacity from about 6,000 to 74,000 bushels, were selected for study; those obviously outdated or inefficient were omitted. Appendix A summarizes some of the pertinent information obtained from field studies.

All data collected from the field studies were compared and evaluated as to the type of building material, the size and amount of handling equipment, the various site arrangements and layouts of facility and the various operations carried on at each facility.

Building materials were compared as to their relative cost of construction, life expectancy, maintenance and repair cost, and efficiency in maintaining the quality of the stored grain. Handling equipment was compared as to size, location, coordination, and functional use. The various site arrangements and facility layouts were compared to determine the best features of each that could be used in developing new and improved designs.

Several preliminary improved designs were then developed. These designs were compared and evaluated with respect to such items as construction costs, annual cost, and general efficiency. The better designs were then selected, given further study and improvement, and are shown as recommended designs in this report.

Scope and Purpose of Report

The layouts and designs illustrated and described in this report are for a small, country grain elevator with a total storage capacity of about 32,000 bushels. The designs were developed mainly for the Southeast where there is a need for a small plant with tanks and equipment for handling, but not storing, large volumes of grain. However, the designs are equally applicable to other areas of the country with similar grain storage and handling needs.

The report includes discussions and recommendations on: (1) Selection of building material and the type of building construction; (2) selection of handling and other equipment; (3) layout and arrangement of the facility; (4) estimated initial construction costs; and (5) estimated annual facility cost including depreciation, interest, maintenance, insurance, and taxes.

Three different types of plants were developed and are described in this report: (1) One handling shelled corn and small grain; (2) one handling ear corn, shelled corn, and small grain; and (3) one receiving mainly ear corn.

The purpose of this report is to provide reliable information for operators who are considering building new facilities; for operators who are planning to expand or alter their existing facilities; and for engineers, equipment suppliers, and others who assist operators in planning, designing, and building grain storage and handling facilities.

It is recommended that storage operators engage a reliable engineer or consult equipment suppliers for further assistance in designing a facility which will meet the specific requirements of each installation.

Before building a new facility, or expanding an existing one, the operator should consider his future as well as his present needs. Crop production trends should be analyzed, harvesting methods and marketing movements studied, and the amount of existing facilities in the area determined.

[1] Plant, facility, or elevator are used interchangeably throughout this report to indicate the buildings, machinery, equipment, utilities, etc., necessary for handling, storing, and merchandising grain.

General Design Assumptions

The following paragraphs set forth the assumptions and criteria used in developing the designs and recommendations used in this report. The selected storage capacities, volume of grain handled, and type of business operations are not based on an economic study of scale of operations but rather on the average type of facility determined from the field studies. Appendix A summarizes data obtained from 19 elevators in the Southeast.

Storage Capacity

A total storage capacity of about 32,000 bushels was selected. This capacity was divided among 4 storage tanks, each with a capacity of about 8,000 bushels. Space and other necessary provisions are made for doubling the storage capacity of the facility under possible future expansion.

Type of Operations

In this report it was assumed that the grain is to be received at the small country elevators in farm trucks and trailers from the field or farm storage, and that most of the grain is to be shipped out by trucks, including large tractor-trailer trucks, to larger or terminal elevators.

The business operation was assumed to be mainly a buying and selling operation with the grain being quickly moved through the plant, usually in 2 weeks or less. At the end of the receiving season, assumed to be about 3 months long, the grain may stay in storage for a maximum period of 3 months. It was assumed that the average annual receipts for the plant would amount to about 10 times the storage capacity of the plant or about 320,000 bushels. These assumed operations are rather typical for many of the plants studied (appendix A).

Handling Capacity

A handling capacity of 4,000 busels an hour was selected for most operations in plants handling shelled corn and small grain. The handling capacity will be lower when cleaning grain or when performing several handling operations simultaneously. For plants receiving only ear corn, a handling capacity of about 1,000 bushels per hour was assumed with provisions for increasing the handling capacity to 4,000 bushels per hour, in the event that shelled corn or small grain is to be received in the future.

The handling capacities selected are greater than those of most of the plants studied. These capacities were selected: (1) To speed up unloading to reduce the waiting lines of trucks during peak seasons; (2) to fulfill an anticipated need for faster receipts with the use of larger grain trucks and larger harvesting equipment; (3) because with vertical type plants high capacity equipment can be installed at a low unit cost; and (4) because research data show that farm trucks of about 140-bushel capacity can be unloaded in a little over 2 minutes.

Structural Design Criteria

The grain storage structure must be designed to safely resist the many loads imposed upon it (fig. 1). The structural design of grain tanks is a complicated problem and should be performed by a competent engineer. The following loads were used in designing and investigating the tanks shown in this report.

Grain loads and pressures.—Janssen's formulas were used for determining the lateral pressures and vertical loads of the stored grain, usually the largest and most critical loads. The exact values for various moving grain loads, eccentric unloading, and changes in pressure due to changes in moisture content are not fully known or agreed upon by authorities. See Appendix B for Janssen's formulas, and additional discussion on grain pressures.

Wind load.—A horizontal design wind pressure of 20 pounds per square foot (15.5 pounds per square foot velocity pressure) for heights less than 30 feet above the ground was used; this wind pressure corresponds to a true wind speed of about 79 miles per hour.[2] For areas close to the Atlantic and Gulf Coasts, and for heights above 30 feet, the design wind pressure should be increased (*34*).[3] The total wind load on the tanks or buildings is the product of the design wind pressure times the projected exposed areas. (For cylindrical shaped tanks, the total wind load is the design wind pressure times the diameter times the height times a factor of 0.6.)

Roof live loads.—A roof load of 20 pounds per square foot of horizontal projection is used (fig. 1). This value covers light snow and miscellaneous construction loads and is a minimum roof load specified by many building codes.

Other loads.—Besides the dead load (weight of the walls and roof), other forces such as seismic, machinery loads supported by the tanks, erection loads, loads developed from thermal expansion or contraction of grain or tank, and loads from any possible internal air pressure in storage tanks should be considered.

Soil bearing capacity.—A soil bearing capacity of 3,500 pounds per square foot was assumed in the designs covered in this report. This subject is discussed under "Tank Foundations," page 16.

Basis and Assumptions Used for Cost Estimates

Construction costs.—The estimated construction costs given in this report are based on labor

[2] This true wind speed corresponds to a recorded wind speed of about 60 miles per hour.

[3] Italic numbers in parentheses refer to items in Bibliography, page 46.

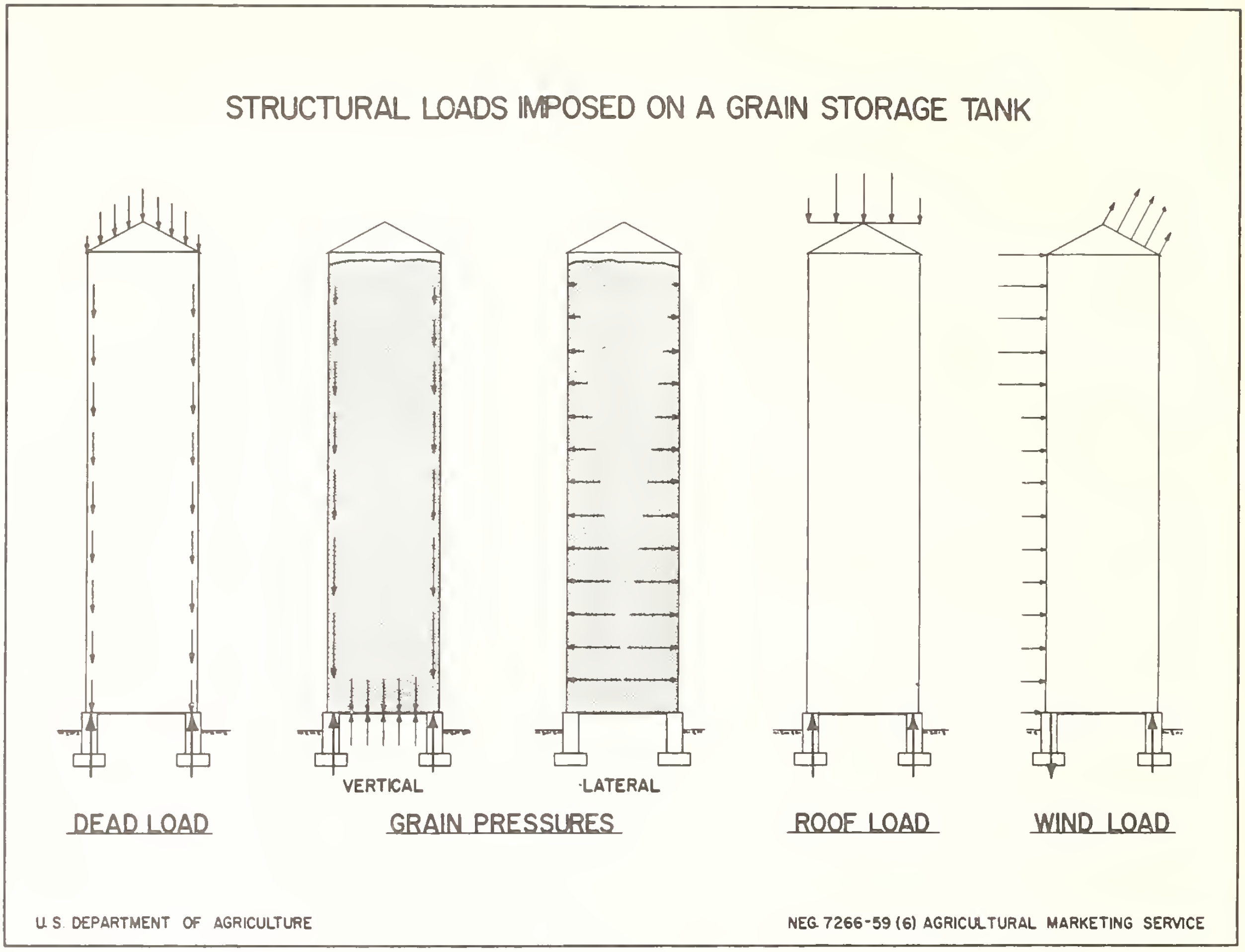

Figure 1.

rates and material prices for the first quarter of 1959 for the Atlanta, Ga., area and on information obtained from estimating handbooks, technical publications, manufacturers of building materials, contractors, and other government agencies.

The storage operator may find considerable variation between his actual construction costs and the estimated costs given in this report, because of: (1) Inherent difficulties in making a precise cost estimate; and (2) conditions existing when and where the elevator is built. The actual construction cost will be affected by site conditions, business conditions, and geographical locations. However, the estimated costs should provide approximate construction costs as well as a basis for comparing different designs.

Annual facility costs.—Annual facility costs include depreciation, interest, taxes, maintenance, and insurance.

The assumed depreciation rates are based on the estimated useful life of the facility. The estimated life for the various tank designs and other parts of the facility is based on observations of existing grain storages, consultation with other engineers, and reference to the following published material: "Income Tax Depreciation and Obsolescense, Estimated Useful Lives and Depreciation Rates," Bulletin F (1942), U.S. Treasury Department, pages 12 and 13; Boeckh, E. H., "Boeckh's Manual of Appraisals," 5th edition, pages 721 to 726; and Kidder-Parker, "Architect's and Builders Handbook," 18th edition, pages 2052 to 2054.

Depreciation cost is a large part of the total annual facility costs and the useful life selected can greatly affect this cost. The useful life of buildings and equipment is dependent not only upon the type and quality of construction but upon shifting land values, changing agricultural practices, quality of building maintenance, and various economic factors. Depreciation as used in this report considers mainly the physical factors such as type and quality of construction. When making construction loans, financial agencies usually assume a more conservative useful life than those used in this report. These, however, do provide a reasonable basis for comparison of the designs.

Other assumed annual facility costs include: Interest on the average investment at 6 percent; taxes at 1 percent of the initial construction cost; maintenance and repairs at 0.7 to 1.3 percent of the initial construction cost, depending upon the type of construction; and insurance at 0.3 to 0.45 percent of the initial construction cost, also depending on the type of construction.

An interest rate of 6 percent appeared to be a fairly typical rate when this report was prepared in 1959. The reader, however, should substitute the interest rate prevailing in his locality when annual facility costs for new or expanded plants are computed. Rates for maintenance and repair costs are based on studies of existing grain storages, and discussions with grain storage operators of their facility maintenance problems. Insurance rates are based on rates furnished by the Insurance Rating Bureaus of North Carolina, Georgia, and Mississippi. Insurance rates can range from 0.09 percent to 2.50 percent of the initial construction cost depending on the type of construction, processing equipment, and exposure.

Insurance on the stored grain.—Insurance rates on stored grain are usually influenced by the type of storage tank the grain is stored in. The rates, including fire and extended coverage, used in this report are based on average rates computed from information obtained from the Fire Insurance Rating Bureaus of Georgia, North Carolina, and Mississippi. The estimated annual insurance cost on the stored grain was computed on the basis that the storage tanks are full to capacity for 6 months of the year and that the grain is valued at $1.50 per bushel.

The operator may find some variation between the insurance rates used in this report and his own rates. The rates will vary with locality and type of fire protection. Rates for extended coverage are usually higher for Seacoast areas. Also, rates are often higher for facilities which have grain dryers or processing activities on the premises and which have exposure hazards.

Factors To Be Considered in Planning and Building a Small Country Elevator

The elevator design is influenced by a number of factors. For example, the number and grades of various grains to be handled will affect the number of bins required. The quantity of grain to be handled daily determines the capacity of the handling equipment. The availability of certain types of building contractors may affect the type of construction selected. Soil and drainage conditions at the site affect size and type of the foundation and other structural components. Local building codes may also determine the type of construction. The shape, and topography of the available building site may greatly affect the layout of the facility.

In planning a small grain storage elevator, the elevator operator should consider the principles outlined in this section which relate to site location, layout, building design, handling machinery and other equipment, and the miscellaneous equipment required to maintain the quality of the grain.

Site Locations

In locating an elevator careful consideration should be given to transportation facilities, utilities, and topography of any proposed building site. The site should be accessible to main roads which can carry large trailer trucks. When rail shipments or receipts of grain are planned, the location and layout of the site may depend mainly upon the railroad access and connections.

The availability of the necessary utilities must be studied. Electric power must be available to operate the handling and other equipment. When a grain dryer is planned for the plant a source of fuel must be investigated. Site investigation should include the determination of a source of water supply for drinking purposes and fire protection and a disposal method for sewage and surface water.

Preferably the site should be square or rectangular and not an irregular shape and it should be reasonably flat, but have sufficient slope for drainage. Surface as well as subsurface soil conditions should be stable to avoid expensive foundation problems. Avoid selecting a site which is adjacent or close to junk yards, garbage disposal areas, and other areas which might be breeding places for rodents.

Layout of Plant

The basic principle of a good layout is to integrate men, materials, and equipment so as to move material over the shortest distance, in the least possible time, and at the lowest cost while providing a natural sequence of operations, in a safe manner and under good working conditions.

The storage bins, office, driveways, parking areas, and other facilities should be arranged to provide for the smooth flow of the grain trucks into and out of the facility and adequate area for trucks to turn and to park should be provided.

The site should be planned for easy supervision of the plant. For example, a bay window in the office building as shown in figure 36, provides the supervisor or weigher with a good view (and thus control) of the trucks and personnel.

Storage bins, equipment, and work areas should be arranged to minimize the handling required for the grain. At some elevator sites the storage bins are located a considerable distance from the work area, requiring additional movement of the grain. A compact arrangement can reduce handling costs as well as damage to the grain from excessive handling.

In planning the elevator layout consideration should be given to potential fire hazards (see section "Dust Control and Fire and Explosion Prevention", below, provision for good working conditions, efficient use of floor space, and provision for future expansion and changing conditions. Cob burners and gasoline storages should be located some distance from the storage bins to provide an adequate fire "break." The position of the various plant components with respect to prevailing winds should be studied in regard to dust control and fire prevention problems.

Buildings and Storage Tanks

Buildings, storage tanks and other structures must be structurally sound; with particular attention given to the structural design of the storage tanks. In many areas the plant will have to be designed according to local building codes. Types of materials and construction methods which will not only minimize construction costs but also reduce annual facility costs should be selected. Non-combustible and fire resistant materials should be used wherever possible. The plant should also be designed to insure the safety of the workers. (See section "Accident Prevention", page 7.)

Well built grain storage tanks help to maintain the market quality and sanitary conditions of stored grain. The grain should be protected from rodents and birds. The walls, roof, and floors should be weather- and fumigant-tight and all joints and openings caulked and flashed as necessary. Ledges and crevices where grain particles can accumulate and provide a breeding place for insects should be avoided. The floors of tanks should be "self-cleaning."

Handling Equipment

The capacity of the various pieces of handling equipment should be carefully coordinated to eliminate "bottlenecks" and reduce waiting time. The handling equipment should be flexible enough to perform the necessary operations such as receiving, shipping, drying, turning, cleaning, and to perform several of them simultaneously. The equipment should minimize crackage and other damage to the grain, and chutes and pits should be self-cleaning.

Machinery and equipment should be easy to maintain and located where it is readily accessible for maintenance and inspection. Dangerous moving parts should be equipped with guards and located away from the main aisles and walkways.

Accessories for Maintaining Grain Condition

A grain dryer should be considered if the receipt of high moisture grain is anticipated (see p. 37). If long storage periods are considered some operators may want to provide an aeration system to keep the stored grain in condition (see p. 21). Generally, it is advisable to install temperature indicators for observing the temperature of the stored grain (see p. 21).

Dust Control and Fire and Explosion Prevention

Combustible dust is produced from grain handling and other operations at a grain elevator. Under certain conditions, the suspended dust particles in the air may produce a highly explosive atmosphere. A spark, electrical arc, a hot metal surface, or an open flame in such an atmosphere can set off a serious explosion, and there have been a number of very destructive explosions in grain elevators. (See Bibliography for a list of published material relative to dust control and explosion prevention.)

Dust control is the first line of defense against a dust explosion. A complete system for dust control, including fans, duct systems, venting, and a central cyclone dust collector, is desirable. Whether a complete system is installed or not the following methods of controlling dust should be included: Sweeping and keeping the premises clean; using construction with minimum ledges and pockets where dust can accumulate; and providing ample windows and louvers to ventilate all work areas. The following locations would be vented or connected with a suction system: Bucket elevators, bins and hoppers, distributors, automatic scales, and loading and discharge sections of belt conveyors (*27*).

To prevent costly fires, operators should consider the installation of automatic sprinkler systems in plants built of combustible materials. Sprinkler heads can be located over fast running main bearings, in the head of elevator legs, under stairways, in covered bins, and in other hazardous areas.

All electrical wiring should conform to the National Electrical Code and all local codes. Explosion proof, electrical fixtures and motors should be provided. Other fire preventive measures include: Having proper fire extinguishers available on the premises, using a fire alarm system, and training and educating employees in fire prevention and fire fighting.

Operators planning new facilities or additions to existing facilities should contact insurance

agencies and fire prevention bureaus for help in planning a fire safe facility.

Accident Prevention

A grain elevator has many potential hazards to personnel working around the plant. Mechanical equipment should be equipped with guards and emergency controls; stairways should have handrails; open shafts and pits should be provided with guard railings; all ladders and catwalks must be well constructed with non-skid surfaces; and ample storage space for tools and supplies should be provided to help promote good housekeeping.

Allied Business

Allied or sideline operations can be an important part of the overall activities of a grain elevator of the size considered in this report. They are often necessary to establish and maintain an economical and sound enterprise and, also, to provide for more efficient use of labor and investments. Fourteen of the 19 plants studied had some kind of an allied business which varied from selling and applying fertilizers and weed killers to selling a complete line of farm supplies. Feed grinding and mixing and the sale of farm supplies accounted for the majority of the sideline operations.

Feed grinding and mixing and the grinding of corn cobs and shucks require considerable horsepower. For example, the total connected load for the feed grinding and mixing operation may vary from 50 up to 150 horsepower. These requirements must be considered in planning any new plant in which these operations are to be performed.

The plants considered in this report can be easily adapted to the milling of edible products such as corn meal, grits, whole wheat flour, and other corn and wheat products. Grains used for these products require good storage, handling, and sanitation practices prior to milling.

Development of the Various Plant Units

For this report the various plant components have been grouped together into 5 functional divisions called units. Improved designs and recommendations were developed for each of these units: (1) Storage unit,[4] (2) receiving unit, (3) office unit, (4) corn-shelling unit, and (5) grain drying unit. The improved plant designs are made up of various combinations of these units.

Storage Unit

As considered in this report the storage unit consists of the tanks or silos for storing the grain plus the necessary handling equipment for moving grain into and out of the tanks. It does not include the equipment for unloading and weighing road trucks which is discussed under other units of the plant.

Capacity, Shape, and Size of Tanks

As stated in the general design assumptions, storage tanks of about 8,000-bushel capacity were selected. Cylindrical shaped tanks were chosen for the following reasons: (1) The many prefabricated or precast tanks of this shape on the market; (2) the tank can efficiently resist the lateral grain pressures; and (3) the tank has a lower ratio of surface area to volume as compared to square tanks and other shapes.

As these designs were developed under the assumption of high annual turn over of grain, flat storages were not considered for the plants discussed in this report.

When several circular tanks are grouped together valuable storage space between the tanks may be wasted. However, interstitial or star bins can be built in this space, especially with reinforced concrete construction. When the circular bins are empty and the interstitial bins full, however, dangerous compressive stresses are produced in the tanks unless they are properly reinforced (*16*). Square tanks can be efficiently grouped together but they must be made sufficiently strong to resist the large bending movements developed in the walls. Several manufacturers are selling square prefabricated steel grain tanks. Hexagonal shaped tanks are a compromise between the square and circular tanks and when a large number of tanks are to be grouped together this shape has certain advantages and should be considered. The final selection of the shape of tank for a particular facility depends on the type of construction material used, the number of bins to be constructed, and the variety of bin capacities desired.

After selecting the basic shape and capacity of the tank it is necessary to determine its dimensions. A tall tank has the following advantages: (1) Only a relatively small amount of storage space is lost with the installation of a hopper bottom, (2) after the grain reaches a depth equal to 2½ to 3 times greater than the diameter of the tank neither the lateral grain pressure on the wall near the tank bottom nor the vertical load on the floor increases appreciably, and (3) a smaller roof and floor area is required for the tank. On the other hand, a short, wide tank has the following advantages: (1) A shorter elevator leg and less power is required to move grain into and out of the tank; (2) less wall area is required; and (3)

[4] Shipping out facilities are considered a part of the storage unit.

the tank is easier to erect, build and repair, and no high scaffolds or cranes are required. See appendix C for further discussions on selecting the dimensions for the tank.

Of course, it is impossible to select a size of storage ideal for all conditions. The final selection will be determined, among other things, by: Available construction materials, site conditions, foundation requirements, and the size of available prefabricated tanks. Figure 2 compares the cost per bushel for various sizes of 8,000-bushel commercial, bolted steel tanks. The 18-foot diameter tank has the lowest estimated construction cost for the sizes shown. The 21-foot diameter tank has a somewhat higher construction cost, but requires an elevator leg having a lower initial and operating cost. With as much spread between the construction cost of the 18-foot and the 21-foot diameter tank, the 18-foot tank may still be the most economical in spite of the added cost of the leg and the higher annual power consumption.

Steel tanks (both welded and bolted) approximately 18-feet in diameter and about 48-feet high and concrete tanks approximately 16 feet in diameter and about 55 feet high were chosen for this report. The exact heights of the tanks varied with the type of bottom. In general, concrete tanks can better resist the larger vertical grain loads resulting from the taller structures.[5] "Slip form" and "jump form" construction is also adaptable for building the taller cast-in-place concrete tanks. In figure 3, the construction cost estimates which compared the cost per bushel of various sizes of concrete stave tanks verify the economy of the taller tanks. Concrete stave tanks over 55 feet high and less than 16 feet in diameter were not considered because of the structural limitations. However, cast-in-place reinforced concrete tanks taller than 55 feet and less than 16 feet in diameter are often practical and economical.

Comparison of Four Types of Construction

The four types of tank included in this study were: (1) Bolted steel, (2) welded steel, (3) con-

[5] Steel tanks over 80 feet high are built, but the large vertical grain loads in such high tanks present a problem in designing against localized buckling in the walls.

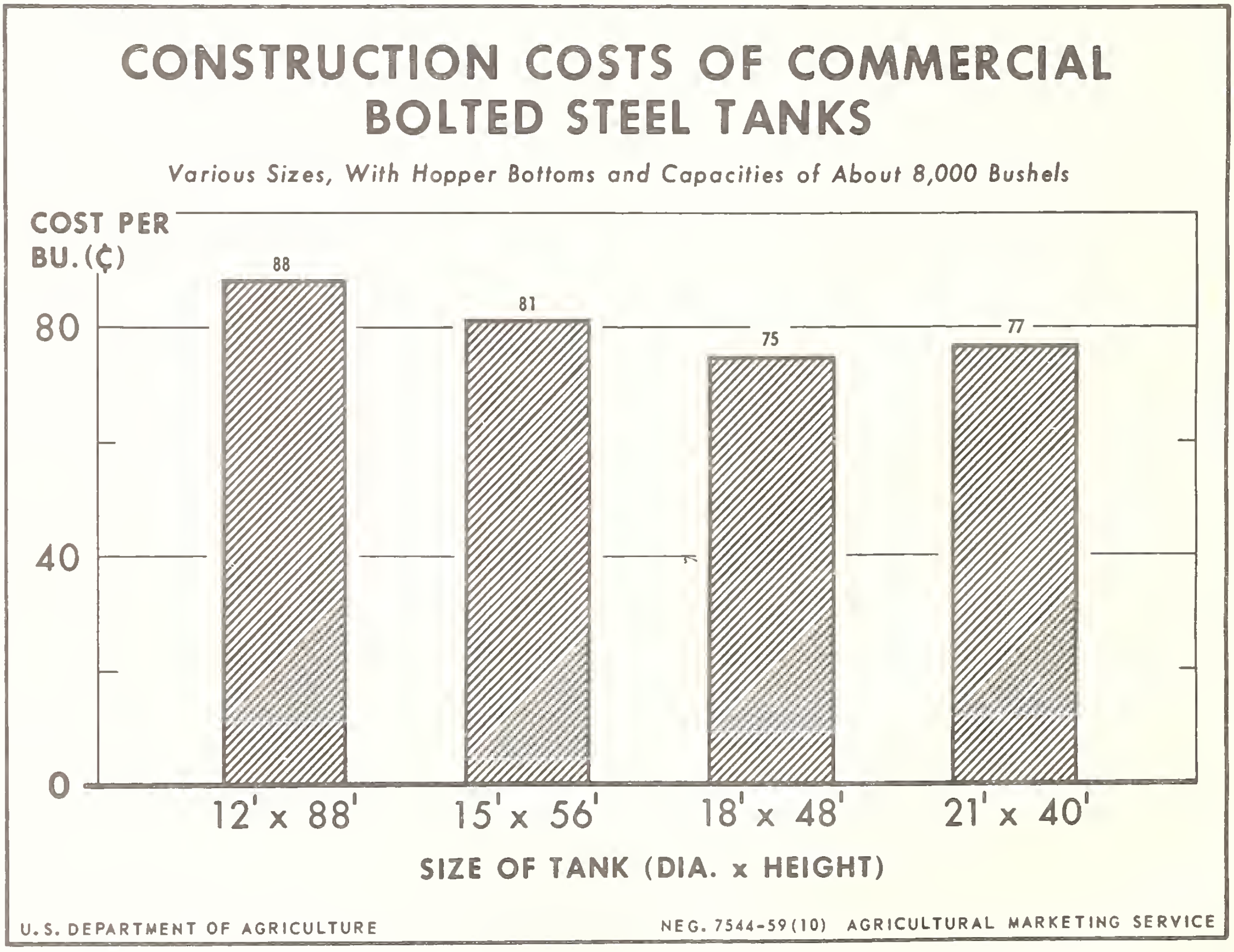

Figure 2.

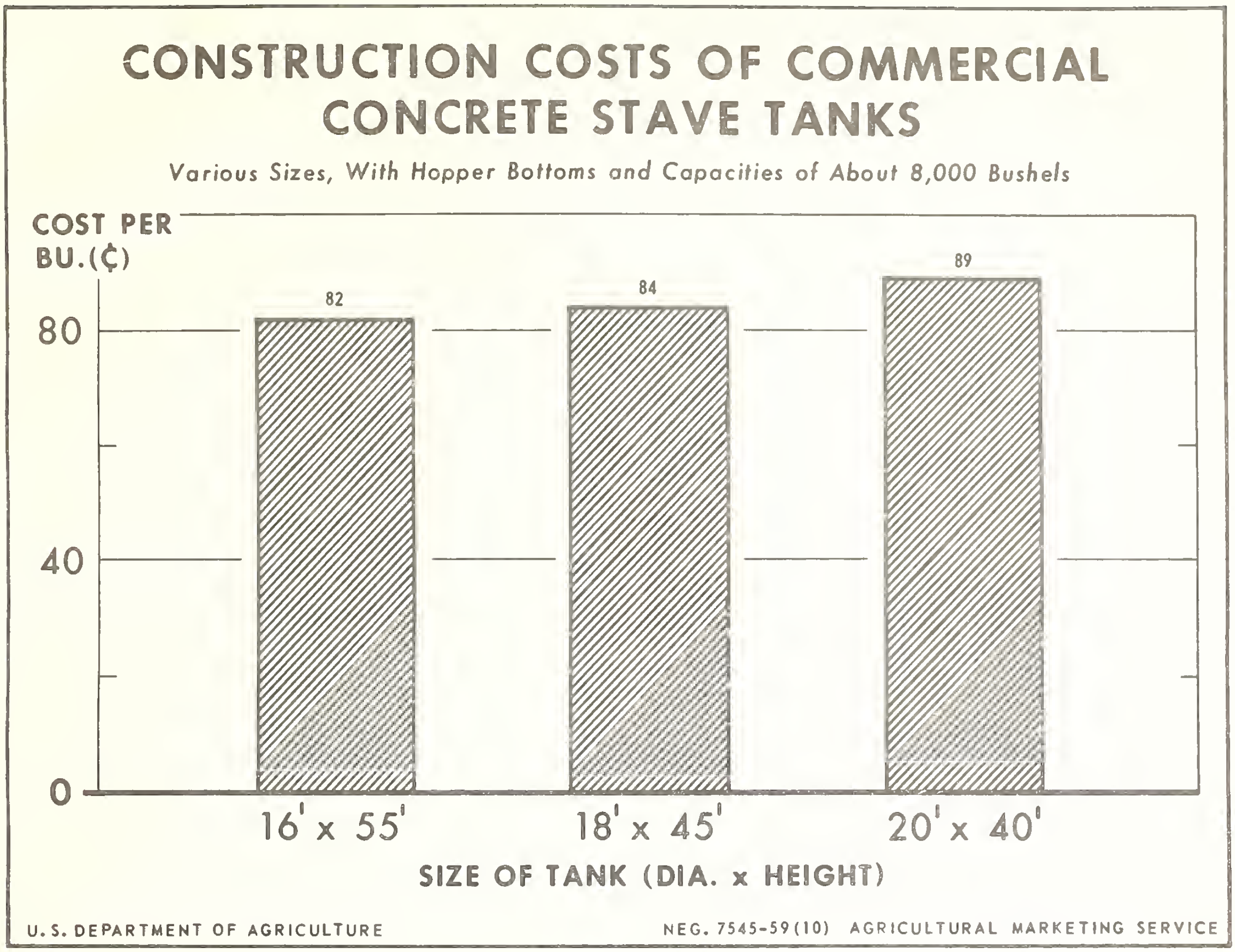

Figure 3.

crete stave, and (4) cast-in-place reinforced concrete.[6] Table 1 compares the costs of these four types of tanks, including initial and annual costs. See section on basis and assumptions used, page 3, for discussion of methods used in arriving at these estimates.

Insurance costs on the stored grain are also affected by the type of tank the grain is stored in. Annual insurance costs for the grain stored in four types of tanks are compared in table 2.

Besides initial and annual costs, consideration should be give to such factors as tank appearance, structural strength, and ability to maintain the market quality of the grain. No attempts were made to evaluate the ability of the different types of tanks to maintain grain quality. However, if the tanks are well constructed any of the four types should perform equally well.

Bolted steel tanks are shown in figures 4 and 5. The larger tanks are usually constructed of steel sheets, 8 feet high by 5 feet wide, bolted together. The sheets vary in thickness from about 7-gage to 14-gage depending on the diameter and height of the tank. The bolted joints are gasketed to make them weathertight. The tanks usually are finished with a coat of aluminum paint but for smaller tanks galvanized sheets may be used. Usually the manufacturer supplies the prefabricated parts and accessories and in some cases erects the tanks on the foundation prepared by the storage operator. In other cases the operator is responsible for erecting his own tanks. In any case it is important to have good workmanship in the erection of bolted steel tanks.

Bolted steel tanks can be quickly erected. Also, they can be easily unbolted, moved to a new location and rebolted with new gaskets, thus being adaptable to a flexible operation. As a rule steel

[6] Other types of storage tanks investigated but not evaluated in this report: A small aluminum grain tank the British have been experimenting with; also, silos and tanks of large precast concrete slabs, each 10 feet long and 15 inches wide, laid horizontally (*31*, *29*). The French have built experimental steel tanks with louvered wall construction (*33*). Reinforced, plastic tanks have been used in this country for storage of chemicals and other products and this type of construction may have a place in grain storage (*32*). Only a few wood tanks were built in 1950.

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TABLE 1.—*Estimated construction and annual facility costs for storage tanks of different construction: 8,000-bushel capacity tanks with flat bottoms* [1]

Type of construction	Construction cost		Annual costs per tank							
	Per bushel cost [2]	Per tank cost	Depreciation		Interest	Taxes	Maintenance	Insurance		Total annual cost
			Useful life [3]	Cost				Rate per $100	Cost	
	Dol.	*Dol.*	*Years*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
Bolted steel	0.58	4,640	22	211	129	46	60	0.45	21	467
Welded steel	.60	4,800	25	192	144	48	50	.45	22	456
Concrete stave	.65	5,200	28	186	156	52	60	.33	17	471
Cast-in-place reinforced concrete	.70	5,600	45	124	168	56	40	.30	17	405

[1] See pages 3 and 4 for basis and assumptions used for cost estimates.
[2] These figures are for tanks with flat bottoms. For information on the cost of hopper bottoms see section "Types of Tank Bottoms," pages 14 and 16.
[3] Depreciation as used here is based mainly on the physical factors such as type and quality of constructions; for accounting purposes in making construction loans, and in business planning a shorter useful life than shown above is often used.

BN-9464-X

BN-9455-X

BN-9453-X

Figure 4.—Plants with bolted steel tanks.

TABLE 2.—*Annual insurance costs on grain stored in tanks of different construction* [1]

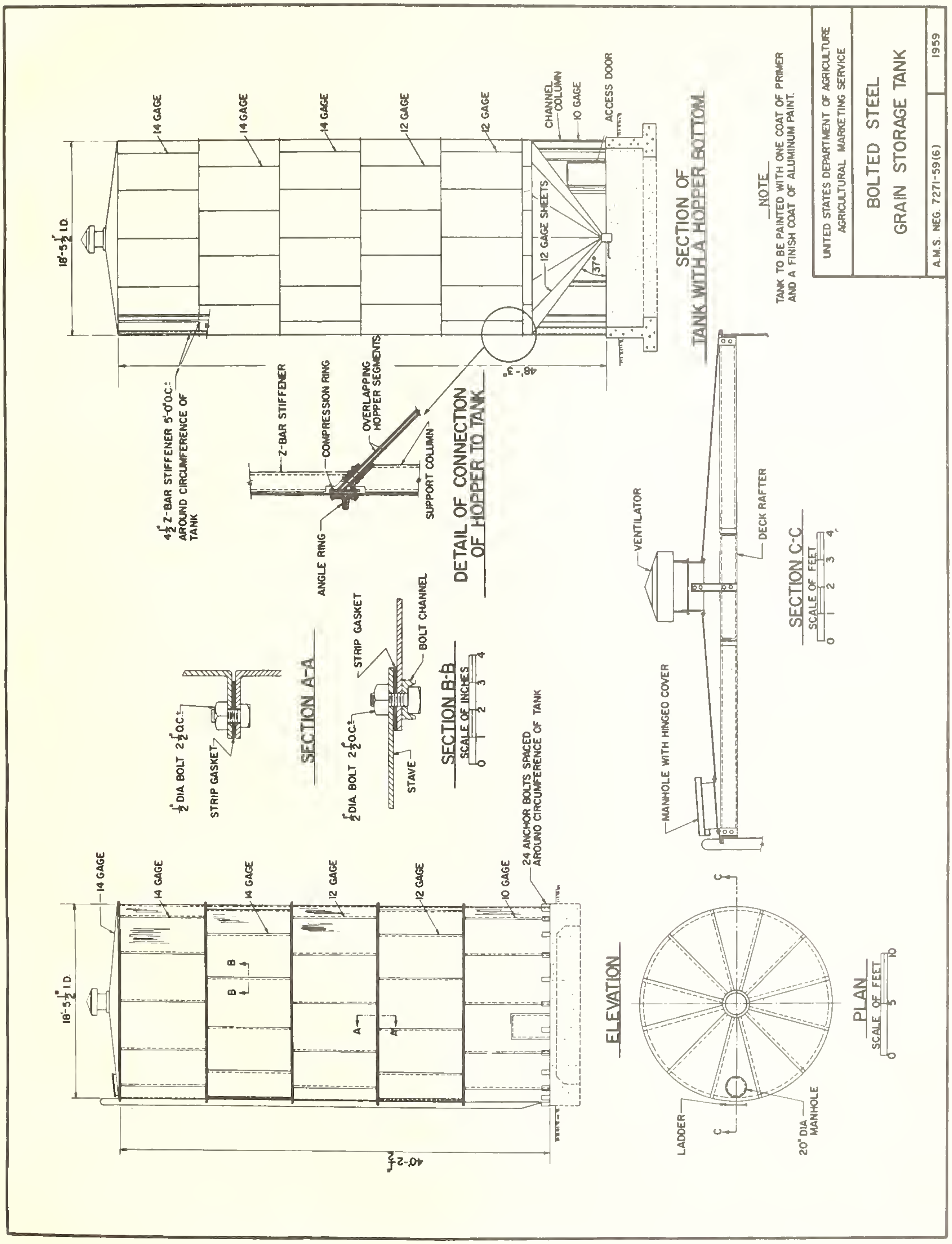
Type of construction	Insurance rate per $100 [2]	Insurance on grain in one 8,000-bushel tank [3]
	Dollars	*Dollars*
Bolted steel	0.37	22.00
Welded steel	.37	22.00
Concrete stave	.28	17.00
Cast-in-place concrete	.26	16.00

[1] See section "Insurance on the Stored Grain," page 5, for basis used in determining insurance costs on stored grain.
[2] The rate for wood tanks may range up to $1 per $100 valuation.
[3] Assumed that grain is $1.50 per bushel and that tanks are full 6 months of the year.

tanks are rodent and weather proof and entirely satisfactory for storing grain. However, some operators report minor leakage at the joints. This usually can be corrected by caulking or adding gasket material. Bolted steel tanks generally require repainting about every 4 or 5 years.

The estimated cost, including foundation and erection, for the bolted steel, without hopper bottom, is $0.58 per bushel of capacity (fig. 5 and table 1).

Welded steel tanks are built of steel sheets welded together (figs. 6 and 7), usually of a heavier gage than that used in bolted tanks. The welded steel tanks studied were fabricated and erected by local steel fabricators located within about 100 miles of the elevator site. The tanks are partially shop welded and then field erected


UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
BOLTED STEEL
GRAIN STORAGE TANK
A.M.S. NEG. 7271-59(6)
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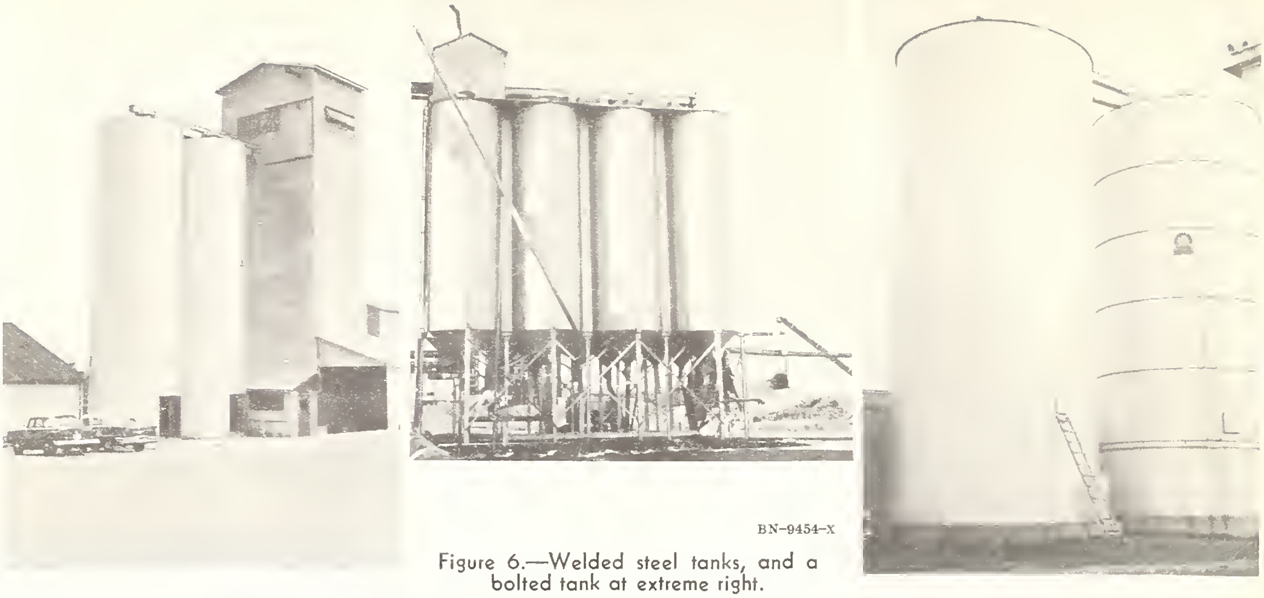
NOTE
TANK TO BE PAINTED WITH ONE COAT OF PRIMER AND A FINISH COAT OF ALUMINUM PAINT.
SECTION OF TANK WITH A HOPPER BOTTOM
18'-5½" I.D.
14 GAGE
12 GAGE
CHANNEL COLUMN
10 GAGE
ACCESS DOOR
12 GAGE SHEETS
37°
48'-3"
4½" Z-BAR STIFFENER 5'-0" O.C.± AROUND CIRCUMFERENCE OF TANK
DETAIL OF CONNECTION OF HOPPER TO TANK
Z-BAR STIFFENER
COMPRESSION RING
OVERLAPPING HOPPER SEGMENTS
SUPPORT COLUMN
ANGLE RING
SECTION A-A
½" DIA BOLT 2½" O.C.±
STRIP GASKET
SECTION B-B
SCALE OF INCHES
BOLT CHANNEL
STAVE
24 ANCHOR BOLTS SPACED AROUND CIRCUMFERENCE OF TANK
VENTILATOR
DECK RAFTER
MANHOLE WITH HINGED COVER
SECTION C-C
SCALE OF FEET
ELEVATION
40'-2½"
PLAN
LADDER
20" DIA MANHOLE

Figure 5.



BN-9454-X

Figure 6.—Welded steel tanks, and a bolted tank at extreme right.

BN-9447-X

BN-9448-X

and welded on the foundation provided by the storage operator. Small tanks, less than about 16 feet in diameter by 40 feet high, have been completely shop welded and then erected at the site by the use of a crane.

A good welded steel tank with continuous welded joints should be completely weather tight. No water leakage was reported in the tanks visited. Welded tanks, being of heavier gage steel, should have a longer useful life than bolted tanks. The smooth walls of the welded tank have no small ledges or crevices to accumulate grain and dust. Little maintenance is required but the tanks should be painted about every 5 years. Welded tanks cannot be dismantled and moved as easily as bolted tanks.

The design as well as the price of welded tanks varied with the different fabricators. The tank shown in figure 7 was developed as an improved design. Without hopper bottom, the estimated cost is $0.60 per bushel of capacity, including foundation and erection (table 1).

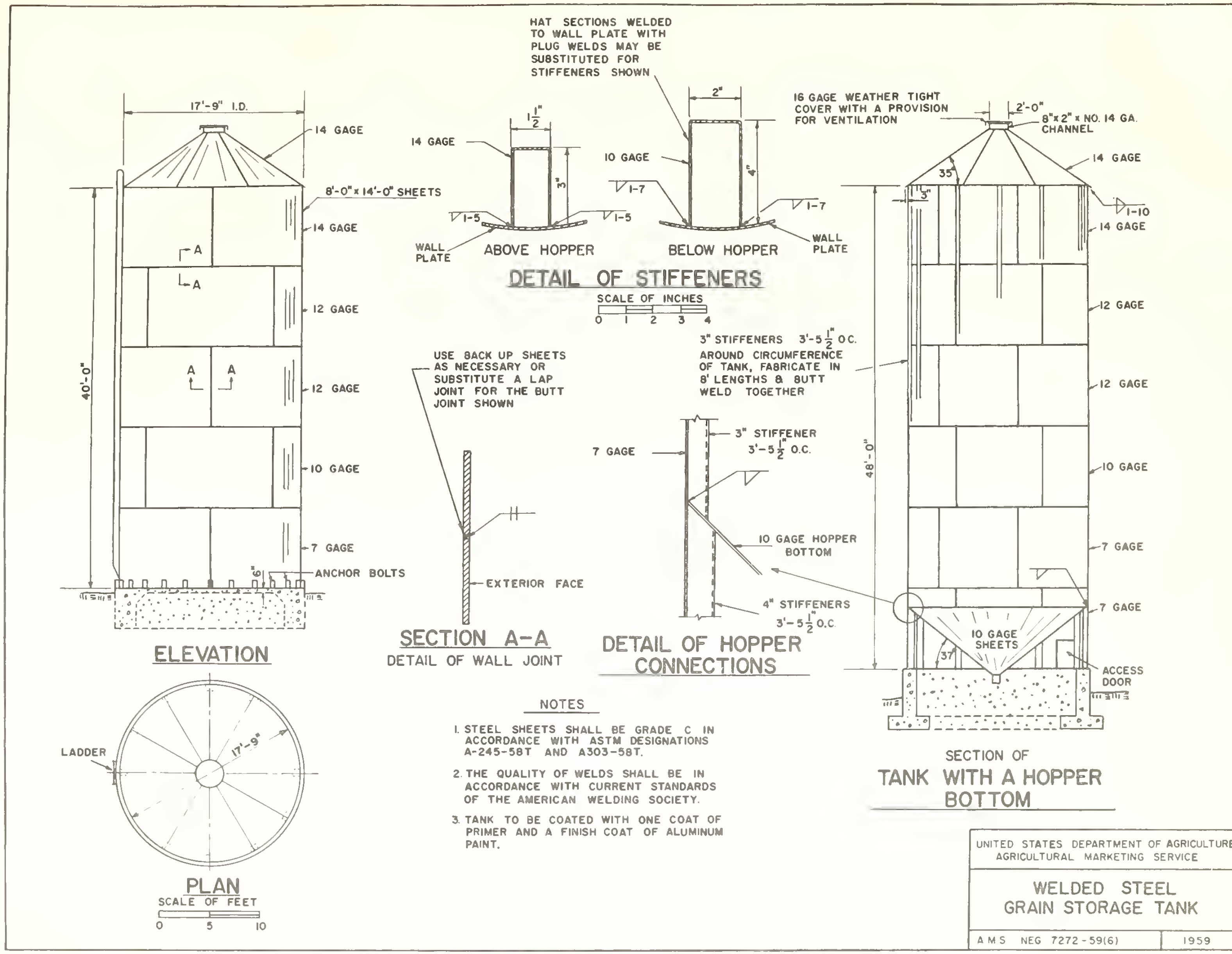
Concrete stave silos or tanks shown in figures 8 and 9 are constructed of precast concrete units or staves usually about 2½ inches thick and 10 inches wide by 30 inches high. The staves are formed of high strength concrete (3,500 to 5,000 PSI 28-day strength) and have tongue and groove joints. Steel hoops of 9⁄16-inch diameter rods are provided to resist the lateral grain pressures. The rods are spaced from about 6 inches on centers at the bottom of the tanks to about 16 inches on centers at the top. This spacing, of course, depends upon the diameter of the tank and the depth of stored grain. The interior and exterior of the tanks are coated with a sand and cement plaster, silicones, or other waterproofing material.

A well constructed concrete stave tank is a durable structure. However, some of the tanks studied had developed minor cracks in the wall joints which permitted the entrance of water and made it difficult to fumigate the stored grain. This type of tank is not strong enough to resist the vertical tensions that could develop in the walls from eccentric grain loads, heavy wind loads, earthquakes, and foundation settlements. The exterior of the tanks should be recoated with some kind of waterproofing about every 5 years.

The estimated cost of this type of tank, without hopper bottom, including erection and foundation is $0.65 per bushel of capacity (table 1).

Cast-in-place, reinforced concrete tanks.—These tanks represent the most permanent type of construction of the 4 types of tanks discussed in this report (figs. 10 and 11). For tanks in the range of capacities covered in this report, the walls would be 5 to 7 inches thick, with horizontal reinforcing rods spaced from about 6 to 18 inches on the centers and vertical rods spaced from about 12 to 24 inches on centers. Construction of the tanks, foundations, and possibly other concrete buildings at the elevator site usually is done by a building contractor specializing in reinforced concrete work. Some of the concrete tanks visited had a few minor cracks. However, the maintenance on a well designed and constructed reinforced concrete tank is negligible.

The estimated construction cost for the concrete tank without hopper bottom, including foundation is $0.70 per bushel of capacity (table 1). However, there was considerable range in the estimates, and the cost may run from $0.50 to $0.95 a bushel for tanks of this size.



17'-9" I.D.
14 GAGE
8'-0" x 14'-0" SHEETS
14 GAGE
12 GAGE
12 GAGE
10 GAGE
7 GAGE
ANCHOR BOLTS
6"
40'-0"
A
A
ELEVATION
LADDER
17'-9"
PLAN
SCALE OF FEET
0 5 10
HAT SECTIONS WELDED TO WALL PLATE WITH PLUG WELDS MAY BE SUBSTITUTED FOR STIFFENERS SHOWN
14 GAGE
1 1/2"
3"
1-5
1-5
WALL PLATE
ABOVE HOPPER
2"
10 GAGE
4"
1-7
1-7
WALL PLATE
BELOW HOPPER
DETAIL OF STIFFENERS
SCALE OF INCHES
0 1 2 3 4
USE BACK UP SHEETS AS NECESSARY OR SUBSTITUTE A LAP JOINT FOR THE BUTT JOINT SHOWN
EXTERIOR FACE
SECTION A-A
DETAIL OF WALL JOINT
3" STIFFENERS 3'-5 1/2" O.C. AROUND CIRCUMFERENCE OF TANK, FABRICATE IN 8' LENGTHS & BUTT WELD TOGETHER
7 GAGE
3" STIFFENER 3'-5 1/2" O.C.
10 GAGE HOPPER BOTTOM
4" STIFFENERS 3'-5 1/2" O.C.
DETAIL OF HOPPER CONNECTIONS
NOTES
1. STEEL SHEETS SHALL BE GRADE C IN ACCORDANCE WITH ASTM DESIGNATIONS A-245-58T AND A303-58T.
2. THE QUALITY OF WELDS SHALL BE IN ACCORDANCE WITH CURRENT STANDARDS OF THE AMERICAN WELDING SOCIETY.
3. TANK TO BE COATED WITH ONE COAT OF PRIMER AND A FINISH COAT OF ALUMINUM PAINT.
16 GAGE WEATHER TIGHT COVER WITH A PROVISION FOR VENTILATION
2'-0"
8" x 2" x NO. 14 GA. CHANNEL
14 GAGE
35°
3"
1-10
14 GAGE
12 GAGE
12 GAGE
10 GAGE
7 GAGE
7 GAGE
48'-0"
10 GAGE SHEETS
37°
ACCESS DOOR
SECTION OF
TANK WITH A HOPPER BOTTOM
UNITED STATES DEPARTMENT OF AGRICULTURE
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WELDED STEEL
GRAIN STORAGE TANK
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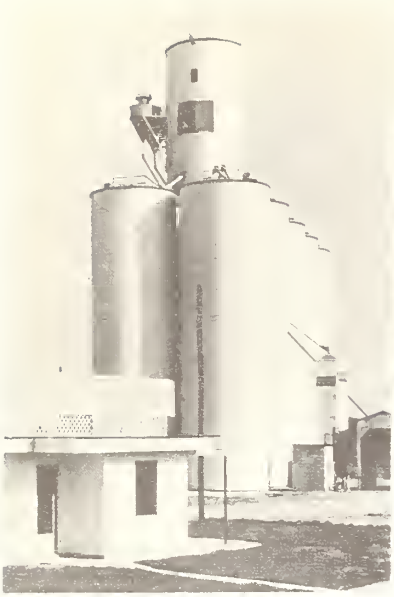
Figure 7.



BN-9458-X

Figure 8.—Plants with concrete stave tanks.

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BN-9466-X

Types of Tank Bottoms

As discussed previously, the plants covered in this report have a large annual turnover of grain; thus, it is desirable to have "self-cleaning" storage tanks that do not require any hand labor to unload. To accomplish this, the tank should be provided with a hopper bottom.

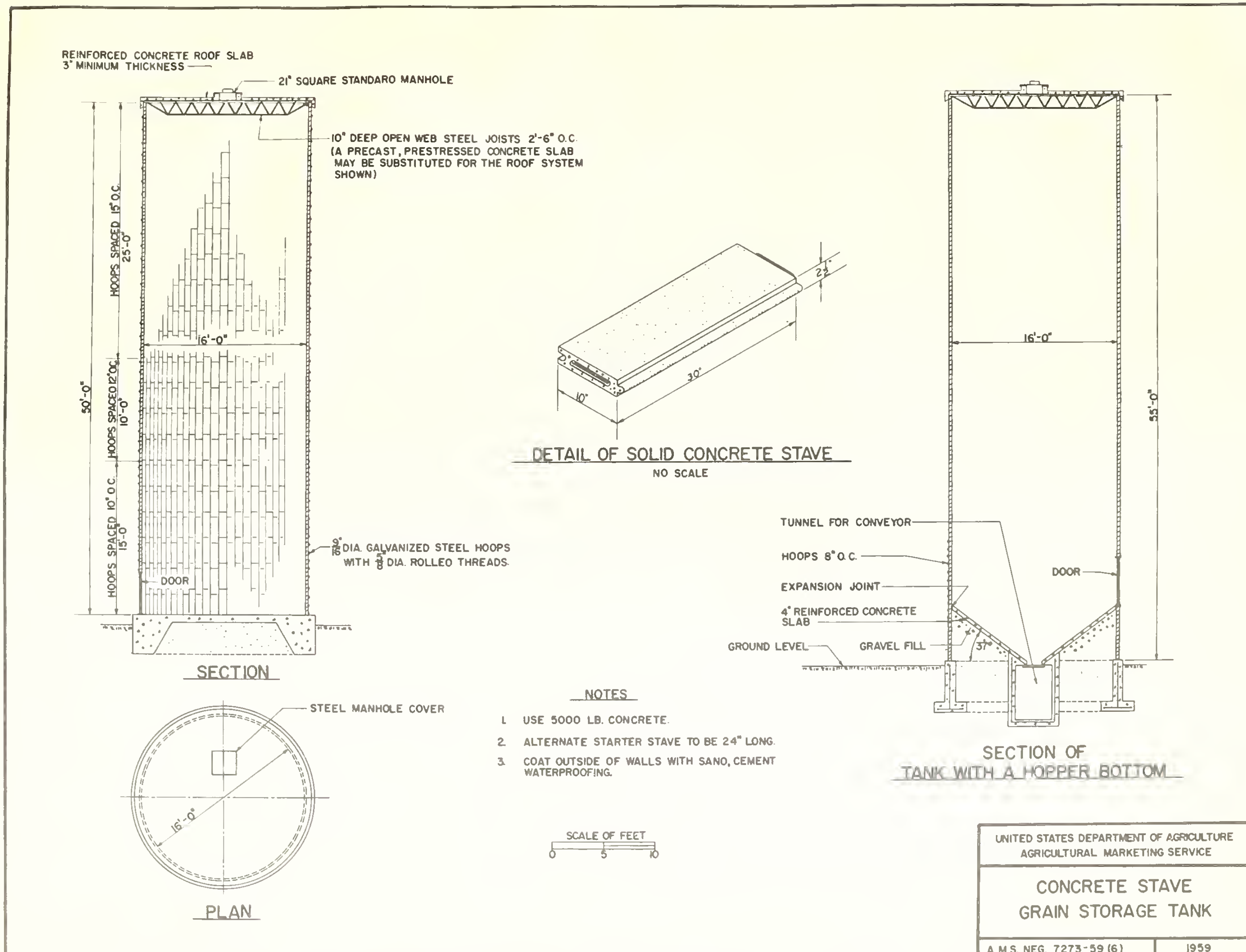
The steel conical hopper is one type of "self-cleaning" tank bottom that is often used. The grain discharges at the center of the tank (fig. 12). Grain discharges into a conveyor located below the center of the tank or the tank is elevated so that grain can discharge into a conveyor or elevator boot located at the side of the tank. These hoppers usually have sloping sides varying from 35° to 45°. Indications are that the 35° hopper is adequate for most dry grains, but the 45° hopper, if provided with an adequate discharge gate, gives more reliable and better unloading of the grain. For the designs used in this report, tank hoppers with a slope of 9 to 12 or 37° are recommended.

The extra cost for adding a 45° steel hopper to a steel tank, 18 feet and 5 inches in diameter, would be approximately $1,200 and about 1,300 bushels of storage space would be lost. The installation of a 37° hopper would cost about $1,100, with a loss of around 1,000 bushels of storage space. The formula shown in figure 13 can be used to estimate the volume of storage lost through the use of a conical hopper as well as to estimate the wasted space at the top of a flat roof tank with center loading.

Despite the high cost of the steel conical hopper it has the advantage of the center discharge which eliminates eccentric loads resulting from side unloading. The steel hopper usually is installed above ground and often is used at sites where drainage and flooding are problems.

Sloping concrete floor.—Figure 14 shows a sloping tank floor consisting of a sloping compacted fill of gravel or sand and cement mixture with a concrete floor slab on the fill. Most storages of this type studied had the floor sloping toward the side of the tank. The slope of the floor may range from about 15° up to 60°. A slope of 35° is considered to be a minimum that should be used and a slope of 37° (9 to 12) was used for the designs shown in this report. To insure reliable grain discharge with side unloading, the floor should be constructed to form a portion of a cone which has a radius equal to twice the radius of the tank (fig. 14). The formula in figure 14 can be used to compute the volume of storage space lost through the use of a sloping floor as well as the wasted storage space at the top of a flat roof tank with side loading. For additional information on wasted storage space see reference (*6*).

The estimated cost for installing a 37° sloping floor of the type shown in figure 14 in a tank 18 feet and 5 inches in diameter would be about $650. This amount includes the concrete floor slab and fill. About 1,700 bushels of storage space would be lost with the sloping floor. This type of sloping bottom costs less than a conical hopper and, with the side discharge, grain can be discharged directly into the boot of the elevator leg or onto a conveyor serving 2 rows of tanks. However, there is the problem of the eccentric loads developed by side unloading and some manufacturers of steel tanks caution against side unloading from their tanks.


REINFORCED CONCRETE ROOF SLAB
3" MINIMUM THICKNESS
21" SQUARE STANDARD MANHOLE
10" DEEP OPEN WEB STEEL JOISTS 2'-6" O.C.
(A PRECAST, PRESTRESSED CONCRETE SLAB MAY BE SUBSTITUTED FOR THE ROOF SYSTEM SHOWN)
HOOPS SPACED 15" O.C.
25'-0"
HOOPS SPACED 12" O.C.
10'-0"
HOOPS SPACED 10" O.C.
15'-0"
50'-0"
16'-0"
DOOR
9/16" DIA. GALVANIZED STEEL HOOPS WITH 5/8" DIA. ROLLED THREADS.
SECTION
STEEL MANHOLE COVER
16'-0"
PLAN
2 1/2"
30"
10"
DETAIL OF SOLID CONCRETE STAVE
NO SCALE
NOTES
1. USE 5000 LB. CONCRETE.
2. ALTERNATE STARTER STAVE TO BE 24" LONG.
3. COAT OUTSIDE OF WALLS WITH SAND, CEMENT WATERPROOFING.
SCALE OF FEET
0
5
10
16'-0"
55'-0"
TUNNEL FOR CONVEYOR
HOOPS 8" O.C.
DOOR
EXPANSION JOINT
4" REINFORCED CONCRETE SLAB
GROUND LEVEL
GRAVEL FILL
37°
SECTION OF
TANK WITH A HOPPER BOTTOM
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AGRICULTURAL MARKETING SERVICE
CONCRETE STAVE
GRAIN STORAGE TANK
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Figure 9.

BN-9461-X BN-9465-X BN-9468-X

Figure 10.—Plants with cast-in-place, reinforced concrete tanks.

Hopper bottom versus flat bottom.—Hopper bottom tanks are expensive and they take up valuable storage space. The following is an analysis of the annual cost for a steel hopper for an 18-foot, 5-inch diameter, 8,000-bushel storage tank:

Extra construction cost for a 45° steel hopper bottom	$1,200
Cost to construct 1,300 bushels of extra storage space @ 50¢ per bushel to compensate for space lost by addition of hopper	650
Total cost	$1,850
Assume a 10 percent annual facility cost (see p. 4)	$185
Assume that the volume of grain handled annually is 10 times the tank capacity (see p. 3) bushels	80,000
Estimated cost per bushel of grain handled	.002

This cost per bushel is low considering the convenience and reliability of unloading from a hopper bottom tank. It is not necessary to have the extra labor and equipment available at exactly the right time as would be required for a flat bottom tank.

On the other hand, operators handling only one type and kind of grain may prefer flat bottom tanks. These tanks may be unloaded as much as possible by gravity flow. The portion of grain remaining can act as the hopper floor and the same kind of grain can be reloaded into the tank. In some areas, however, the portion of grain acting as the hopper may become infested with insects or spoiled and would have to be removed.

Tank Foundations

The design of a foundation for small bolted steel tanks is simple if the soil is stable. On the other hand, the design of foundations for large reinforced concrete elevators can be a complex engineering problem. In the plants studied, the foundations varied from a small concrete slab to extensive pile foundations. Not only must the foundation resist the vertical loads of the stored grain and the tank, but foundations for high tanks must resist the overturning force of high winds and earthquakes. Where several tanks are erected on one concrete slab, unbalanced loading of the foundation can result with some tanks full and others empty (*10*). It is particularly important that all tanks on a slab be loaded uniformly the first time they are loaded. Uneven and excessive settlement of the foundation may cause cracks in the tanks and sometimes even complete structural failure of the tanks. For large storage structures or where unstable soil condition exists, the foundation should be designed by an engineer experienced in foundation design. Site borings and soil tests should be made to determine bearing capacities.

As stated in the design assumptions, a soil bearing capacity of 3,500 pounds per square foot was used for the designs in this report. Most coarse, sandy soils, or compacted clay soils, should have a soil bearing capacity of at least 3,500 pounds but many soft clay soils may have only one-half this bearing capacity.

Tank Arrangement

Four tanks with capacities of about 8,000 bushels each were combined to form the storage unit with a total capacity of about 32,000 bushels. The tanks were grouped closely together to permit

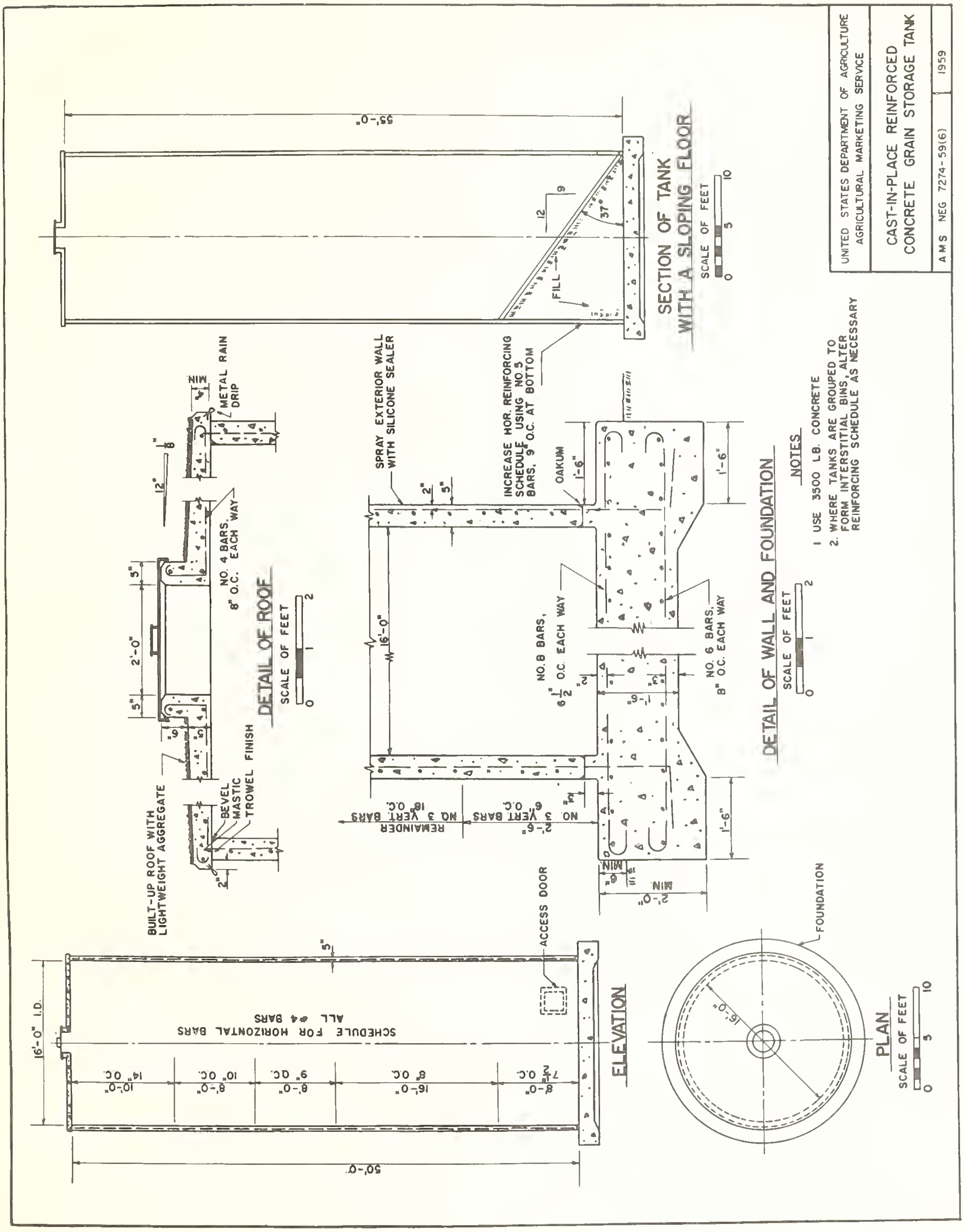

Figure 11.

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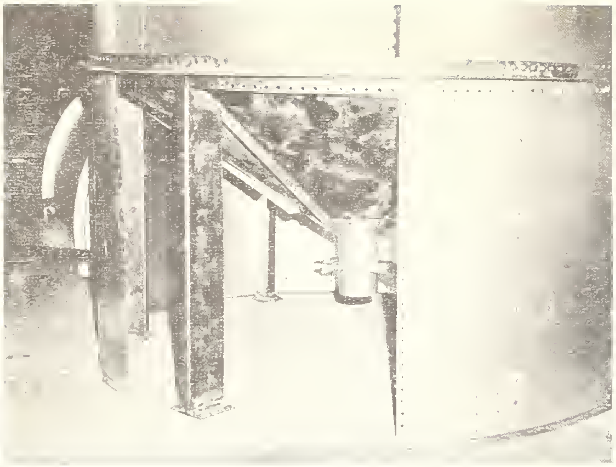

BN-9457-X

Figure 12.—Conical steel hopper bottom.

grain to flow directly from the dump pit into the boot of the elevator leg (fig. 15). This arrangement provides for rapid and reliable unloading of grain trucks. By using an elevator leg tall enough, grain can flow by gravity from the top of the leg into all 4 tanks. Grain can be moved from the tanks to the boot of the leg by gravity or by means of a belt conveyor. More details of arrangement and layouts are discussed under the 3 plant designs on pages 38, 44, 45.

Grain Movement or Handling

The storage unit must be provided with the necessary handling equipment for moving grain into and out of the tanks. Because the tanks are grouped closely together, the grain movement is mainly vertical. The vertical screw has been used for handling small quantities of grain; however, power requirements are high and there is the possibility of damaging and mixing of grains during handling. For the capacities recommended in this report the vertical screw is not considered practical. Pneumatic systems are flexible and clean but require considerable horsepower. The bucket elevator is most commonly used for moving grain vertically and was selected for the designs illustrated in this report. It causes little damage to the grain, has a relatively low initial cost, and low power requirements.

The bucket elevator leg consists of a series of buckets mounted on a belt operating over an upper pulley in the head and a lower pulley in the boot (fig. 16). The bucket line, the top pulley, and lower pulley terminals should be enclosed in a dust tight steel casing. The casing should be provided with clean out and inspection openings; necessary ladders and platforms should also be provided to simplify inspection and maintenance of the leg.

The bucket elevator is a source of fire hazard and should be designed, operated, and maintained

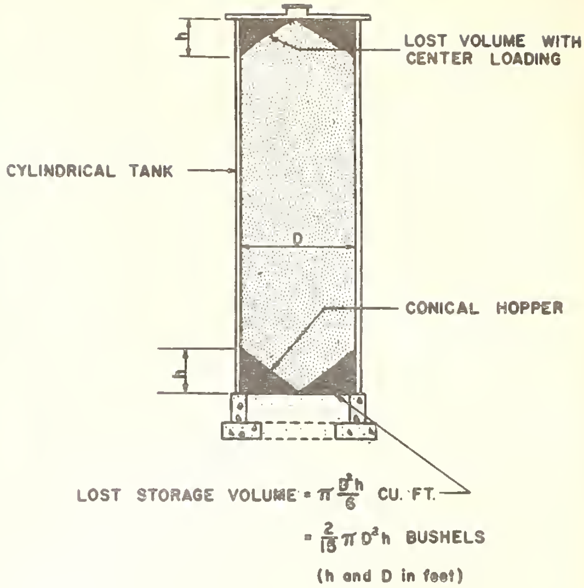

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Figure 13.—Cylindrical tank showing lost storage volume with center loading and unloading. The formula shown can be used for computing the lost storage volume at either the top or bottom of the tank. For lost volume at the top of the tank, *h* is determined by measurement or from calculations using the angle of repose of the grain; at the bottom, *h* is determined by the height of the hopper.

in accordance with recommendation of fire prevention agencies. To prevent the bucket line from revolving the wrong way and causing serious choke-ups, an automatic backstop is required. Gear reduction drives can be equipped with mechanical ratchets, magnetic brake shoes, or other arrangements to act as a backstop. The elevator should have anti-friction bearings and should be equipped with slanting strut board under the head pulley to prevent grain accumulation (fig. 16). A motion switch can be installed to stop the motor if the boot pulley does not operate at the correct speed (rpm) or if the belt breaks or is too loose.

From the head of the elevator the grain moves to the tanks through a distributor and spouting. Many operators find that, after their elevator is built, spouting is either too flat or not large enough to handle sufficient grain. For the designs in the report, 8-inch diameter spouting on a 10 to 12 slope is considered a minimum size and slope. Spouting is usually 16 or 14 gage steel—often of a special alloy to resist the abrasion of the grain. Spouts that carry considerable grain, for example, from the head to distribtutor should be heavier gage. In selecting a distributor it is desirable to have extra outlets for future expansion. The movable spout on the distributor should be controlled from the ground floor level by means of cables.

The compact arrangement of the tanks, the leg high enough to feed grain by gravity into the

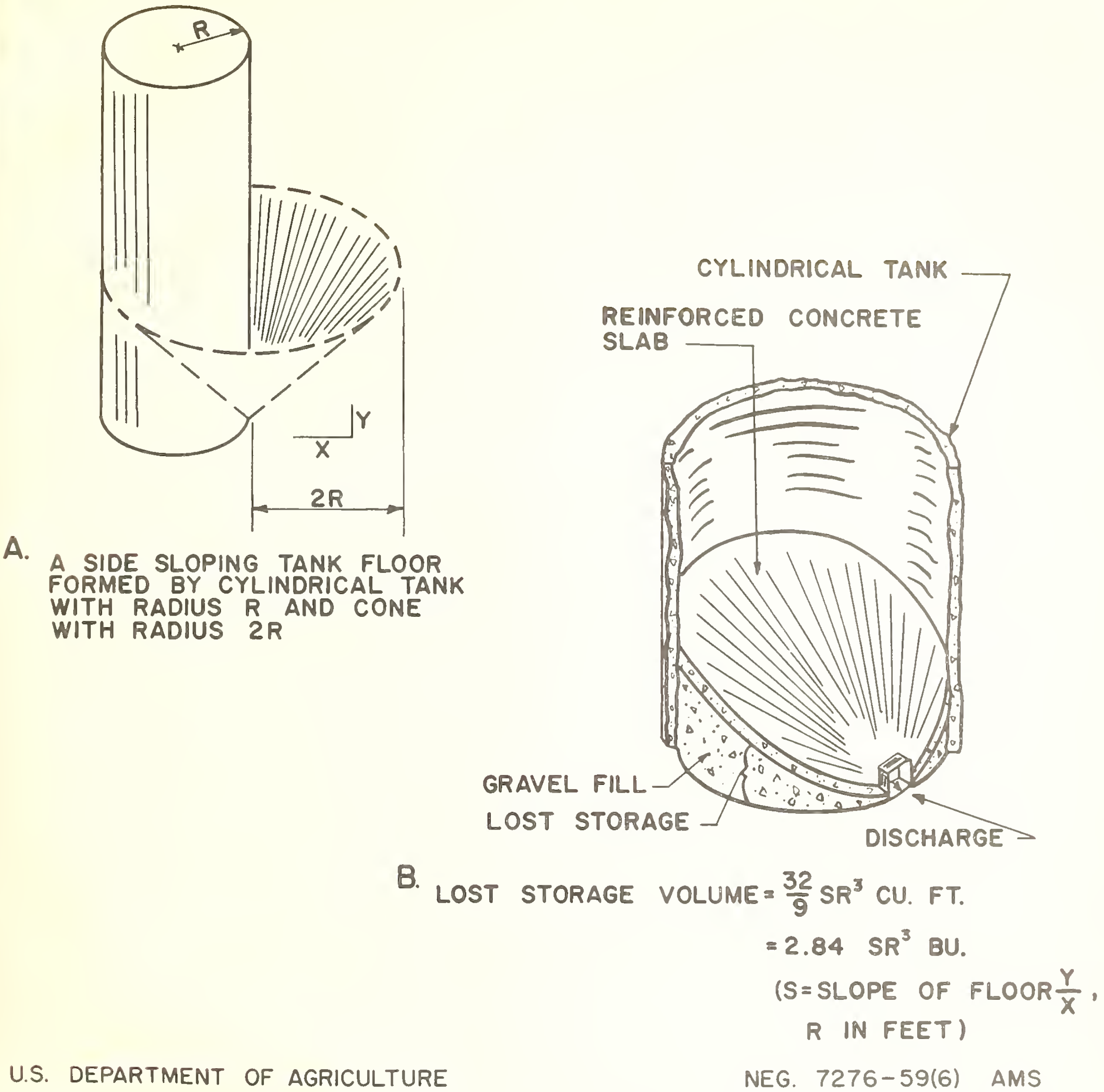

Figure 14.—Lost storage volume with sloping floor to tank side.

tanks, and the side sloping tank bottoms eliminate the need for horizontal conveyors. However, with any future expansion horizontal conveyors would be required above and below the tanks. Either a belt conveyor—basically and endless belt supported by idlers and driven by a pulley with drive motor—or a screw conveyor—a rotating screw in a stationary trough—could be used. If the grain must be unloaded into various tanks at selected points along a belt conveyor, a tripper arrangement is required. A belt conveyor must also be protected from the weather by some type of housing. Any conveyor should be installed with anti-friction bearings, and approved type of enclosed motor with overload protection, and other features to make the installation safe from fire and explosion. Proper guards must be provided on all equipment to protect workers in the area. Conveyors for handling ear corn are discussed under the shelling unit, page 36.

Grain Cleaners

The grain cleaner is used to separate sticks, cobs, straw, chaff, and other foreign material from the grain. Most cleaners use reciprocating screens and fans. Many of the storages studied used

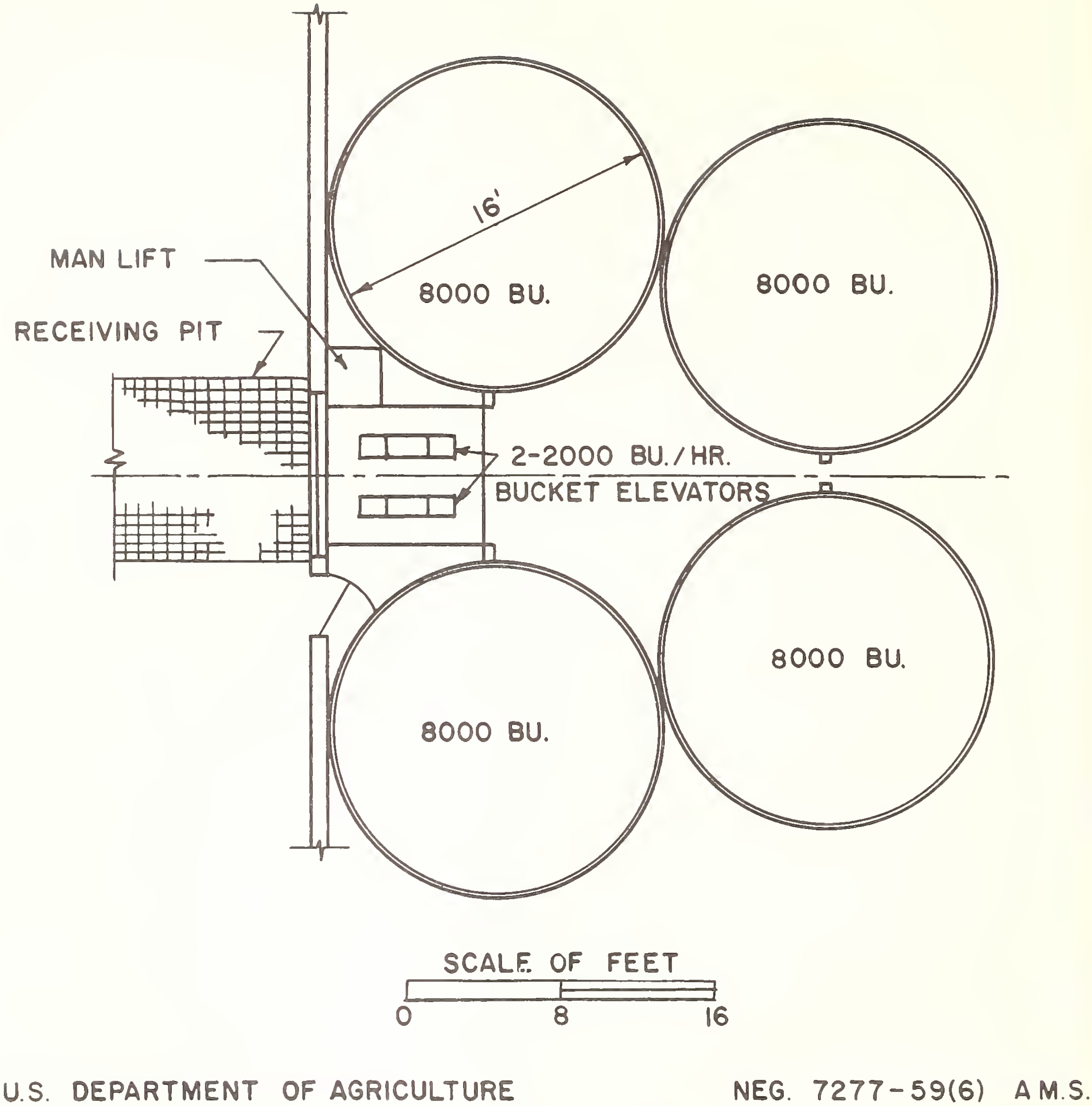

Figure 15.—Layout of storage unit.

scalper cleaners which removed only the sticks and other large foreign material.

The cleaner should preferably be constructed of steel or other noncombustible materials. Where the cleaner is located in the headhouse above the tanks, a cleaner geared to the capacity of the elevator leg should be used. For the designs illustrated in this report a minimum capacity of 2,000 bushels per hour (capacity of 1 elevator leg) is recommended. Operators planning to clean a large percentage of grain received should consider a 4,000-bushel per hour cleaner. Where the cleaner is located below a holding bin or an interstitial bin, a smaller cleaner (about 1,000 bu. per hour) should be sufficient. In selecting a cleaner to meet his requirements the operator must carefully consider the location and capacity of the cleaner, and type of screens for it.

One shortcoming of existing cleaner arrangements studied was that often no adequate provision was made to collect and dispose of trash—sticks, fines, and chaff—coming off the cleaner. The trash was often collected in bags as it came off of the cleaner, requiring constant attention during cleaning operations. Small collection bins should be provided to hold this material and some

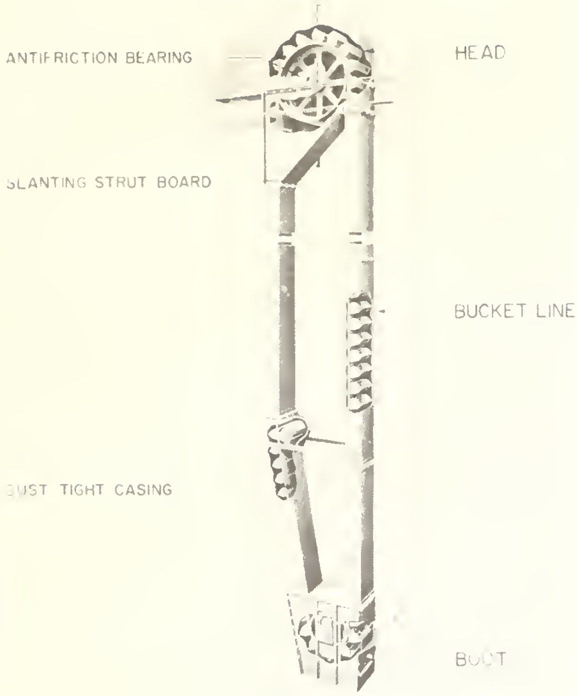

Figure 16.—Bucket elevator.

means provided to conveniently load the material into trucks (fig. 43–B). Usually two or more of these bins should be provided in order to keep the various types of foreign materials separated.

Automatic Scales

Automatic scales are used in many grain elevators for weighing grain as it is being loaded into rail cars. The scales may be located anywhere in the elevator easily accessible to the grain flow, and where it is convenient to service and to reach them for manual weighing of partial draft. Frequently they are located in the headhouse and the grain, discharged from the elevator head, flows into the scales and then out of the scales by gravity.

Little grain was shipped out by rail from most of the small plants studied in the Southeast. They did not, therefore, have automatic or manual scales for weighing rail shipments. Generally, weights recorded at terminal elevators or other major shipping points were accepted.

Aeration

Grain aeration (*36*) is being widely accepted in commercial elevators. In the elevators considered in this report, the turnover of grain is relatively fast and aeration may not be too necessary. However, operators planning to hold grain in storage long enough to require turning of the grain should consider installing an aeration system—at least in 1 or 2 of their tanks. Research results and industry experience show a possible saving of at least one-half cent per bushel for aeration over turning during a storage season. Aeration cools grain and provides a practical and economical means of fumigating it without moving it. Although aeration is not a substitute for drying wet grain, it can keep damp grain (up to 15 percent moisture content) for short periods of time before it is moved to terminal elevators for drying.

The main parts of an aeration system are the duct, or ducts, located in the grain, from which air moves into or out of the stored grain; one or more fans move the required amount of air; a motor operates each fan; and supply pipes connect fan and duct. If an aeration system is to work effectively, the parts must be carefully selected. And, attention must be given to the storage tanks as well as to the aeration system.

For example, assume that an aeration system is to be provided for the concrete tank (55 feet high and 16 feet in diameter) described in this report. A single floor duct is generally used in a tank of this size. This may be a semicircular perforated corrugated duct, or some other acceptable type of duct.

Again assume that 8,000 bushels of shelled corn are to be stored in the tank and that an airflow rate of one-tenth cubic feet of air per minute (cfm) per bushel is to be provided. A semicircular perforated duct, 9 feet long and 24 inches in diameter (widest dimension) would be satisfactory. Other suitable types of ducts with a total of 27 square feet of perforated surface area would also be satisfactory.

A fan that will deliver the 800 cfm at a static pressure of about 2 inches of water will be required. With a well-designed fan a ¾- to 1-horsepower electric motor should be large enough. Thermostats and humidistats can be used to operate the fan only during suitable aerating weather; or the fan can be controlled manually.

Ducts could be installed in more than one tank and the one fan moved from storage to storage. However, one fan should not be expected to aerate more than 2 or 3 tanks for any length of time.

The aeration system could also be used to aerate 8,000 bushels of wheat stored in this tank. But the airflow rate would be reduced to about 1/20 cfm per bushel and the static pressure would be increased to about 3.5 inches of water. See reference (*36*) for more information on the design, operation, and cost of aeration systems.

Grain Temperature Indicators

Usually any spoilage or insect infestation in stored grain is accompanied by an increase in grain temperature. To know the temperature of the stored grain, therefore, helps the operator to know the condition of his grain. The regular use of temperature indicators will help the operator in deciding when to turn his grain, how much

to turn, and when and how much to fumigate. It is particularly desirable to use grain temperature indicators in connection with an aeration system to determine when and how much to aerate.

Thermocouple cables are widely used as grain temperature indicators. These cables are made up of insulated thermocouple wire reinforced by steel cables with the wire and cable being encased in an abrasion—and fumigant—resistant casing. Thermocouple junctions for indicating grain temperatures are located at 3- to 7-foot intervals along the cable. The thermocouple cables generally are installed permanently in the grain bin and should be well anchored. The cables usually are connected by lead wires to a conveniently located panel where grain temperatures can be easily and quickly read with a portable or stationary potentiometer.

Miscellaneous

Magnetic separators.—Scrap metal in grain is a potential hazard and a worry to elevator operators; it can cause damage to equipment and costly delays, particularly during rush periods. Fires in grain elevators have resulted from friction heating of scrap iron lodged in the system. Dust explosions may be caused by sparks from scrap metal striking against other metal.

Magnetic separators can be used to eliminate some of these hazards. They may be attached to a grain chute or located where they will separate the metal from the grain as it passes on a belt conveyor. Magnetic separators are not costly and any operator planning a new grain elevator should consider their installation.

Static arresters.—Fast moving belts and conveyors may create "static electricity" that can start fires or cause dust explosions. Static arresters are used with belt elevators and conveyors to reduce these hazards.

Electrical equipment.—Electricity is the main source of power and light in any modern commercial industry. All electrical wiring, lighting, controls, motors, and motor starters located in dusty areas should be suitable for operation in hazardous locations (National Electrical Code, Class II, Group G). They should be installed in accordance with any local codes.

All electrical work should be approved for location and should be properly fused and protected with overload devices to prevent any excessive load on the electrical circuits that could cause heating and eventual fire.

The 440-volt motors with suitable wiring, usually cost less than lower voltage motors and it is recommended that they be used where available. Lower electrical losses occur when the higher voltages are used.

Manlifts in grain elevators provide vertical transportation of personnel from one floor level to another and thus quick access to equipment on all floors. Many insurance agencies and States have strict regulations on the installation and operations of manlifts.

The motor operated, cage type, one- or two-man lift is commonly used for safe, dependable, and fast transportation. The one-man lift is suggested for the designs used in this report.

Two other types of man-lifts used sparingly in small country elevators are the continuous-belt lift and counter-balanced, one-man platform lift. Safety hazards involved with these types of lifts limit their use.

Grain testing equipment is a necessary part of any grain receiving and handling operation. This equipment consists mainly of a sample divider, a grain moisture tester (generally of the electronic type), a dockage tester, sieves and the necessary balance for determining the foreign material present in the grain, and a standard apparatus for determining the test weight per bushel. Other test equipment includes a small balance scale for weighing the sample to be used for moisture test; thermometer for sample temperatures; cans for holding grain samples; and grain samplers, either a scoop type for obtaining a sample as the grain flows from the truck, or a probe to obtain a sample from the loaded truck.

Car loaders.—Some of the elevator designs included in this report show the rail siding on the office side. The car loading spout in these designs may not have sufficient slope to fill a rail car by gravity flow. For this, some designers recommend at least a 50-foot straight spout with a slope of 2 to 1. One type of car loader commonly used is a short, high speed belt type driven by an electric motor (fig. 17). As the grain flows onto the fast moving belt, it is thrown to the ends of a rail car. The complete assembly is relatively small and can be positioned to give the desired direction and length of throw to the grain. An air blast car loader is another type of loader often used.

BN-9463-X

Figure 17.—Rail car loader.

Ladders, catwalks, and platforms should be provided for easy access to various parts of the elevator for making inspections, equipment adjustments, and repairs.

The Receiving Unit

The grain receiving unit includes the grain receiving or dump pit, truck hoist, and the building for housing those facilities. At some small elevators the truck scales are combined with the receiving unit; at other elevators the truck scales are included with the office unit. A comparison of these two different scale arrangements will be discussed later in this section.

Shortcomings in Existing Unloading Units

During the field studies several shortcomings or defects were noted in many existing receiving units.

In some plants the dump pit was too small (fig. 18) causing a bottleneck in unloading operations.

BN-9451-X

Figure 18.—This small unloading pit is a bottleneck.

Many dump pits were not properly covered with gratings causing a safety hazard to personnel working around the pit.

At some elevators, the loaded grain trucks had to climb a steep ramp or incline when entering the unloading area (fig. 19). The trucks often stalled on these ramps causing annoying delays especially during the peak receiving season. At some plants trucks had to back up to the unloading pit (fig. 20) which also caused delays. Some unloading areas were not adequately sheltered (fig. 21) and this prevented or hindered unloading during inclement weather.

Advantages and Disadvantages of Combining the Truck Scale With the Receiving Unit

At many elevators the truck scale and office were located several hundred feet from the unloading facilities and storage tanks. This arrangement

BN-9449-X

Figure 19.—There is no level approach for trucks entering the receiving unit and loaded trucks often stall climbing the steep ramp.

BN-9456-X

Figure 20.—Trucks have to back up to receiving pit to unload.

BN-9460-X

Figure 21.—No shelter over this receiving pit.

facilitates the smooth and rapid flow of trucks during unloading. Also, the office is free from dust and noise resulting from unloading operations.

On the other hand, locating the platform scale in front of the dump pit and including it with the receiving unit, near both the office and storage tanks, makes a compact layout. Also, empty trucks do not have to be rerouted for reweighing—sometimes a cause of bottlenecks in traffic. Except during the peak season, one man often is able to operate the entire elevator including weighing, dumping, sampling, and testing. However, the noise and dust from unloading operations can be disturbing to office personnel. This problem can be partially solved by using: (1) Insulated walls or partitions for separating the office and unloading areas; (2) doors equipped with thresholds and rubber wipers; (3) caulking for openings or cracks in walls; (4) windows with double glazing; and (5) air conditioning for the office area.

With the truck scale and dump pit together receiving operations may be about 15 percent slower than where the scales are separate from the receiving unit. For the small country elevator, the compact, labor-saving arrangement of scale and dump pit together may be the most advantageous.

Recommendations and Improved Designs for the Receiving Unit

The following discussion and drawings cover suggestions and recommendations for the receiving unit and its various components. The storage operator, of course, should modify these recommendations as necessary to meet his particular needs.

Layout.—Figure 22 shows a recommended layout for the unloading unit where the dump pit is

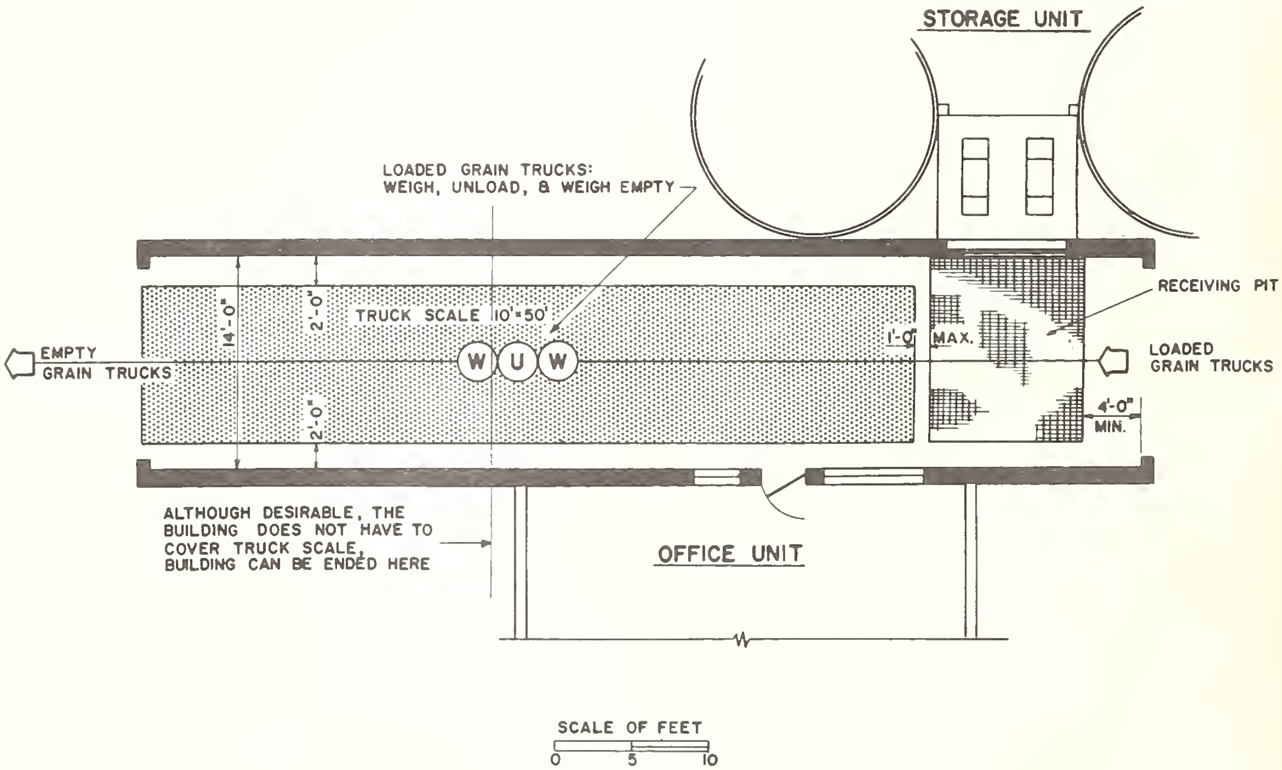

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Figure 22.—Layout for the receiving unit.

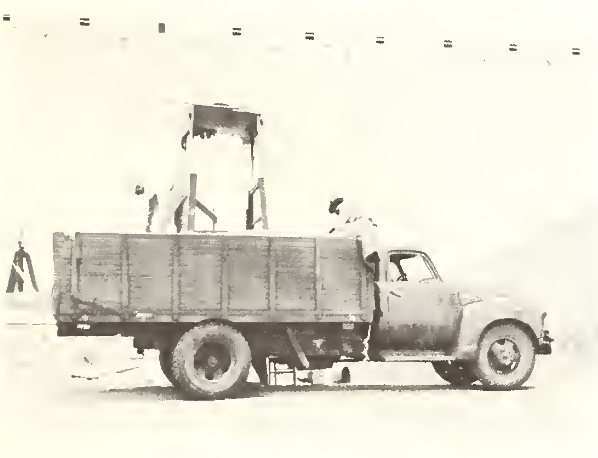
located directly behind the truck scale. With this arrangement, trucks enter the receiving unit and weigh, unload, and weigh empty. To reduce or eliminate backing of the truck after it is weighed, lines, markers, or some type of electrical device can be used as a guide in stopping the truck just after the back wheels have moved onto the scales.

There should be sufficient clearance on either side of the platform scale for walkways (fig. 22). There also should be sufficient clearance between the dump pit and the entrance to the pit shelter to protect unloading operations from inclement weather.

At some elevators the dump pit is an integral part of the platform scale. With this compact arrangement trucks do not have to back up to unload after being weighed. However, the steel members of the scale often limit the width of the dump pit to about 7 feet, and when the truck's tail gate is fully open during unloading, the grain will usually form a stream wider than 7 feet. Thus, more cleaning and sweeping up is required.

For further discussion on elevator layouts, see the sections covering the complete elevator facility designs.

Truck hoist.—At small country elevators in the Southeast, grain is received in trucks of various sizes. These range from small pick-ups to larger "bobtail" grain trucks (fig. 23). The large trucks will carry from 200 to 330 bushels of grain with the maximum weight of truck and load being not over 30,000 pounds. As the front wheels probably carry a maximum of 25 percent of the gross weight, a hoist for lifting the front end of the truck should have a minimum rated capacity of 4 tons. Truck hoists with 5-ton rated capacity are recommended for the designs covered in this report. Occasionally grain may be received in large trailer trucks and the 5-ton hoist would not be adequate to lift these trucks. But most operators of small country elevators consider it uneconomical to install a truck hoist large enough to lift the occasional trailer trucks.



BN-9445-X

Figure 23.—A "bob-tail" grain truck.

BN-9444-X

Figure 24.—Electric truck hoist.

With the type of truck lift suggested the truck's front wheels rest in a cradle which is raised by an electric hoist supported by an overhead bridge crane (fig. 24). The entire hoist and frame travel back and forth on tracks. For a 5-ton hoist, at least 5-horsepower motor should be provided and the hoist should be capable of lifting the truck at the minimum rate of 18 feet per minute.

In some areas farmers have hinged the rear of the truck's grain body and provided rings on the front end of the body for raising it. The truck hoist must then be provided with hooks for engaging the lifting rings. Also, the bodies of small tractor-trailer trucks can be raised for unloading with this arrangement.

To provide sufficient slope for dumping the grain, the bridge crane supporting the overhead truck hoist should be at least 14 feet above the floor level (fig. 25). However, often the tail gate, tail light, or back bumper of some small farm trucks will strike the floor and this will determine the maximum angle to which the truck can be raised. Often regular grain trucks can be continued to be raised after the tail end of the truck hits the floor although the rear wheels are lifted off the floor.

Grain receiving or dump pit.—The grain receiving or dump pit should: (1) Have a large enough opening at the floor level to eliminate or reduce sweep up; (2) have a large enough volume to hold one and preferably two truckloads of grain; (3) be tight enough to prevent grain leak-

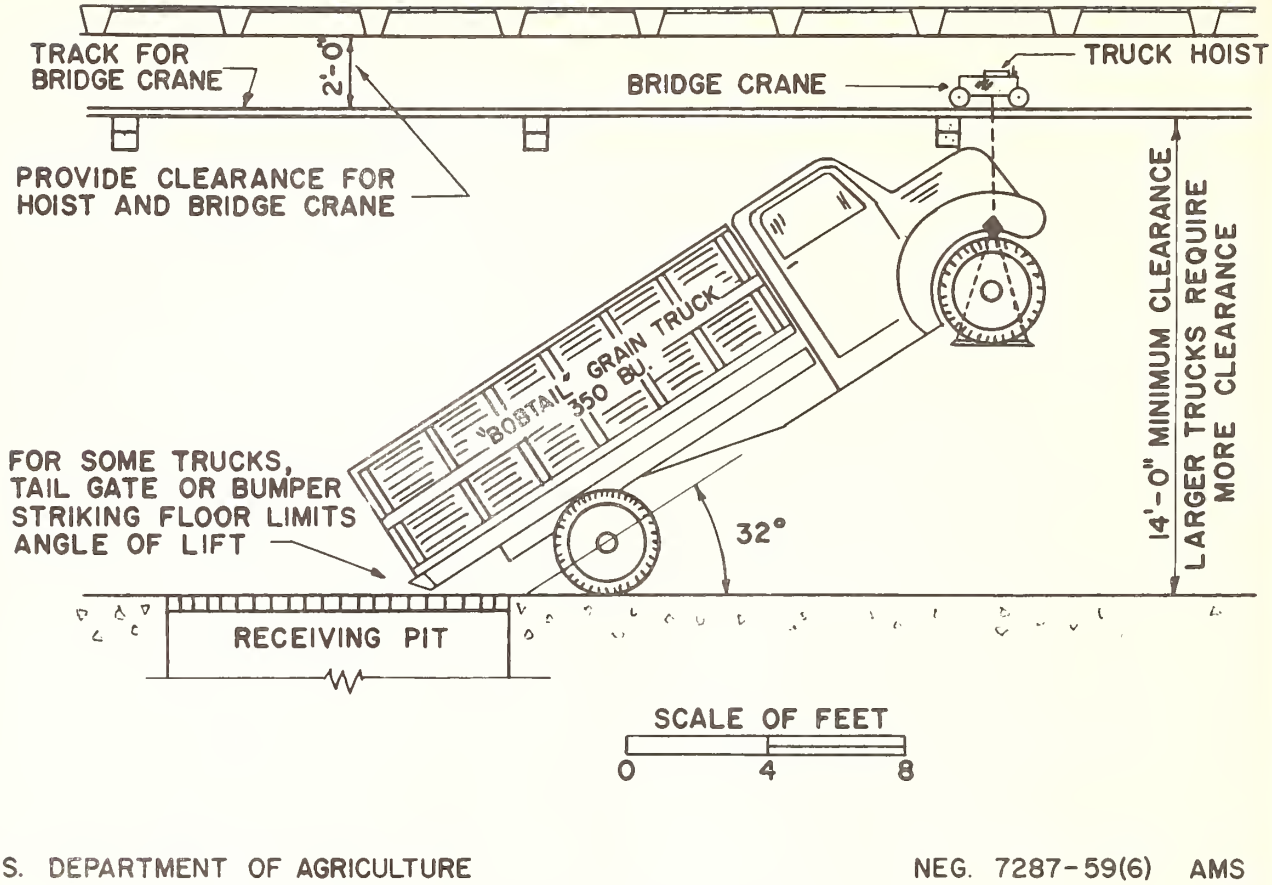


Figure 25.—Vertical clearance required for unloading grain trucks.

age from the pit or water leakage into the pit; (4) have sufficient side wall and valley slope to be self-cleaning; and (5) be covered with a safe, strong grating.

In the plants studied the size of opening of the pit (at floor level) varied from as small as 3 feet by 4 feet, to as large as 8 feet by 12 feet. To eliminate, or at least reduce, the labor required for cleaning up it is recommended that the pit opening be at least 8 feet by 12 feet and even larger where the pit is remote from the scale.

It is desirable that the pit hold from 400 to 600 bushels. This will hold the load of the largest "bobtail" grain truck, or two average trucks, or a small tractor-trailer truck. This pit is larger than any studied but was selected so that the pit could serve as a holding bin during unloading operations. This is important during delays caused by changing spouts, making adjustments on the elevator leg, etc. Operators anticipating larger truck loads and long waiting lines of loaded trucks should consider even a larger pit.

The grain hopper or pit should be grain tight and waterproof. Many of the elevator sites along the Coastal Plains of the Southeast have a high water table and drainage problems. Consequently, many elevators have a problem of water leaking into the receiving pit or the elevator boot pits.

The following are recommendations for insuring dry grain pits: (1) Select as favorable site and soil conditions as possible, (2) lower the water table with drainage lines, (3) elevate pit and driveway above existing ground level, (4) make concrete walls and floors as impermeable as possible by using low water cement ratio, impermeable aggregate, well proportioned mix, etc., (5) provide sufficient reinforcing to resist soil and hydrostatic pressures, (6) give careful consideration to the design and construction of joints (see details of joint in Section B–B, figure 29); and (7) cover or coat concrete walls with membrane waterproofing or cement-based compounds if necessary. A sump pump can be installed where conditions are severe.

The walls of the pit should have sufficient slope to be self-cleaning. Careful consideration should be given to the angle of the valley where the flat sides of the hopper intersect as this angle is less than the angle of the intersecting sides. The alinement chart in figure 26 gives the valley angle for various angles of intersecting hopper sides. To insure rapid and reliable unloading, a minimum slope of 40° from the horizontal is suggested for the valley angles and a greater slope is desirable.

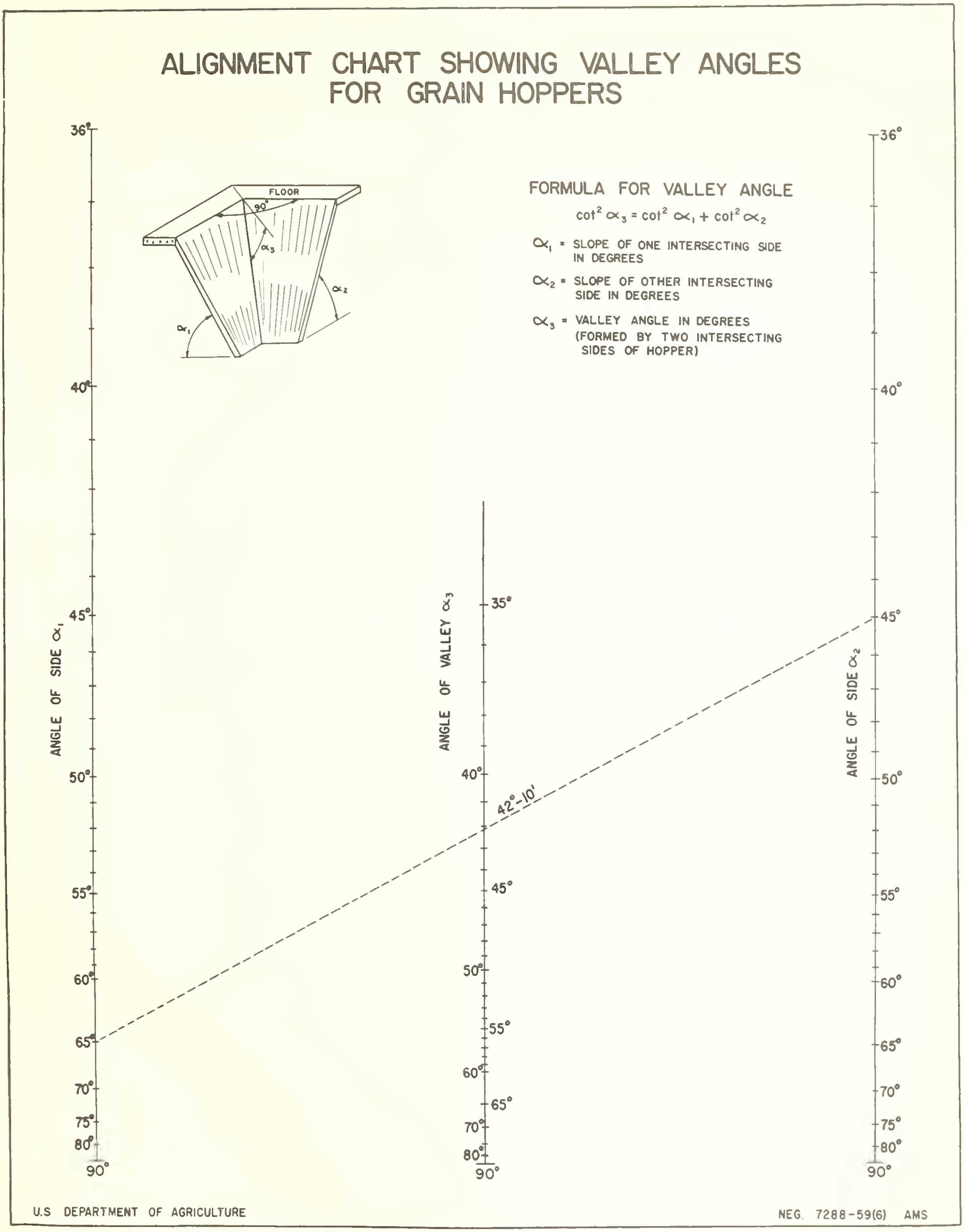
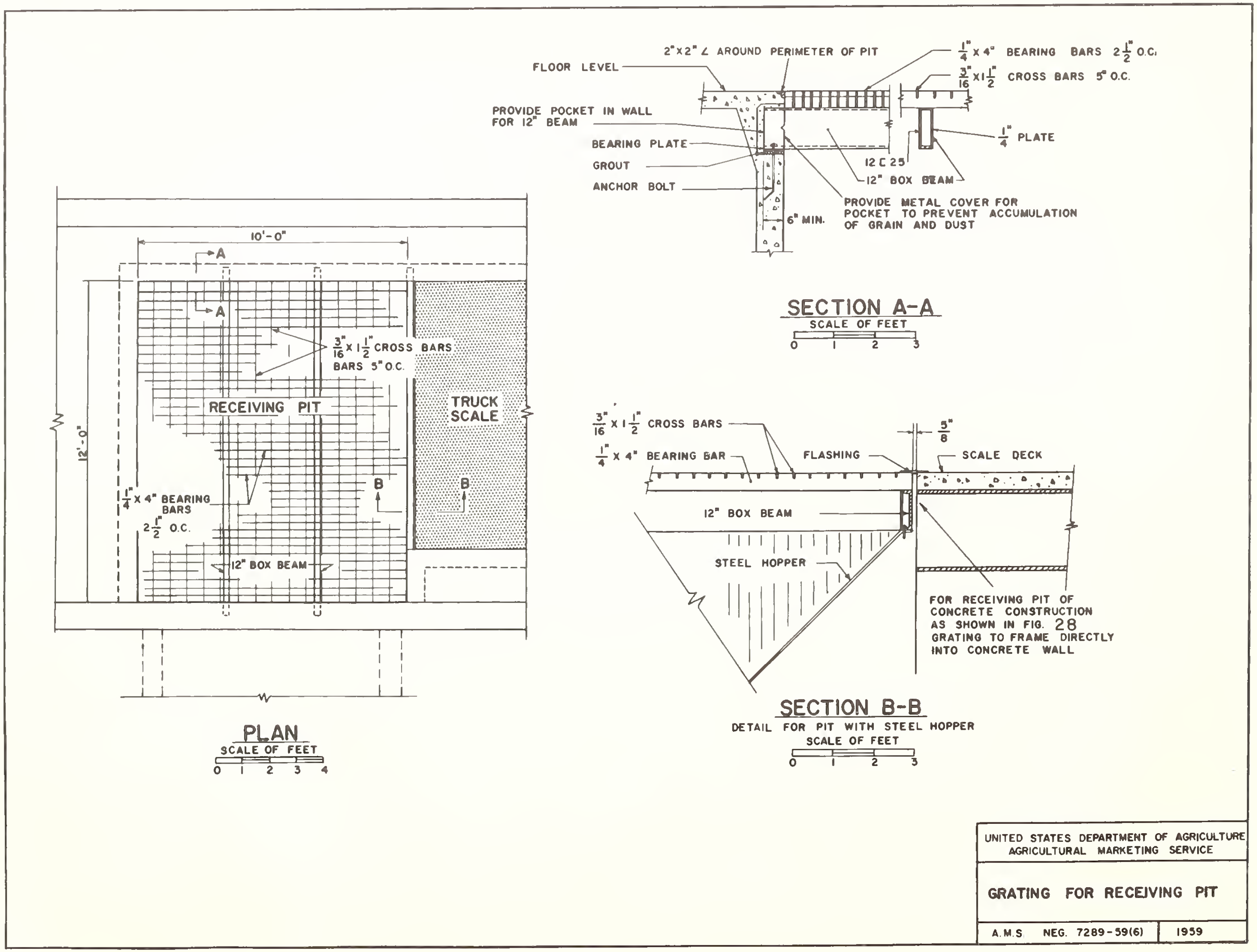


Figure 26.—To determine the volley ongle formed by two intersecting sides of hopper: (1) Ploce a stroightedge on either scole ot side of chort at a known ongle of one hopper side. (2) Ploce the other end of stroightedge on other scole at side of chort ot the other known side angle. (3) Reod the volley ongle where the stroightedge intersects the center scole of the chort.



FLOOR LEVEL
2"x2" ∠ AROUND PERIMETER OF PIT
1/4" x 4" BEARING BARS 2 1/2" O.C.
3/16" x 1 1/2" CROSS BARS 5" O.C.
PROVIDE POCKET IN WALL FOR 12" BEAM
BEARING PLATE
GROUT
ANCHOR BOLT
1/4" PLATE
12 [25
12" BOX BEAM
6" MIN.
PROVIDE METAL COVER FOR POCKET TO PREVENT ACCUMULATION OF GRAIN AND DUST
SECTION A-A
SCALE OF FEET
0 1 2 3
10'-0"
12'-0"
A
RECEIVING PIT
3/16" x 1 1/2" CROSS BARS
BARS 5" O.C.
TRUCK SCALE
B
1/4" x 4" BEARING BARS
2 1/2" O.C.
12" BOX BEAM
PLAN
SCALE OF FEET
0 1 2 3 4
3/16" x 1 1/2" CROSS BARS
1/4" x 4" BEARING BAR
FLASHING
5/8"
SCALE DECK
12" BOX BEAM
STEEL HOPPER
FOR RECEIVING PIT OF CONCRETE CONSTRUCTION AS SHOWN IN FIG. 28 GRATING TO FRAME DIRECTLY INTO CONCRETE WALL
SECTION B-B
DETAIL FOR PIT WITH STEEL HOPPER
SCALE OF FEET
0 1 2 3
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GRATING FOR RECEIVING PIT
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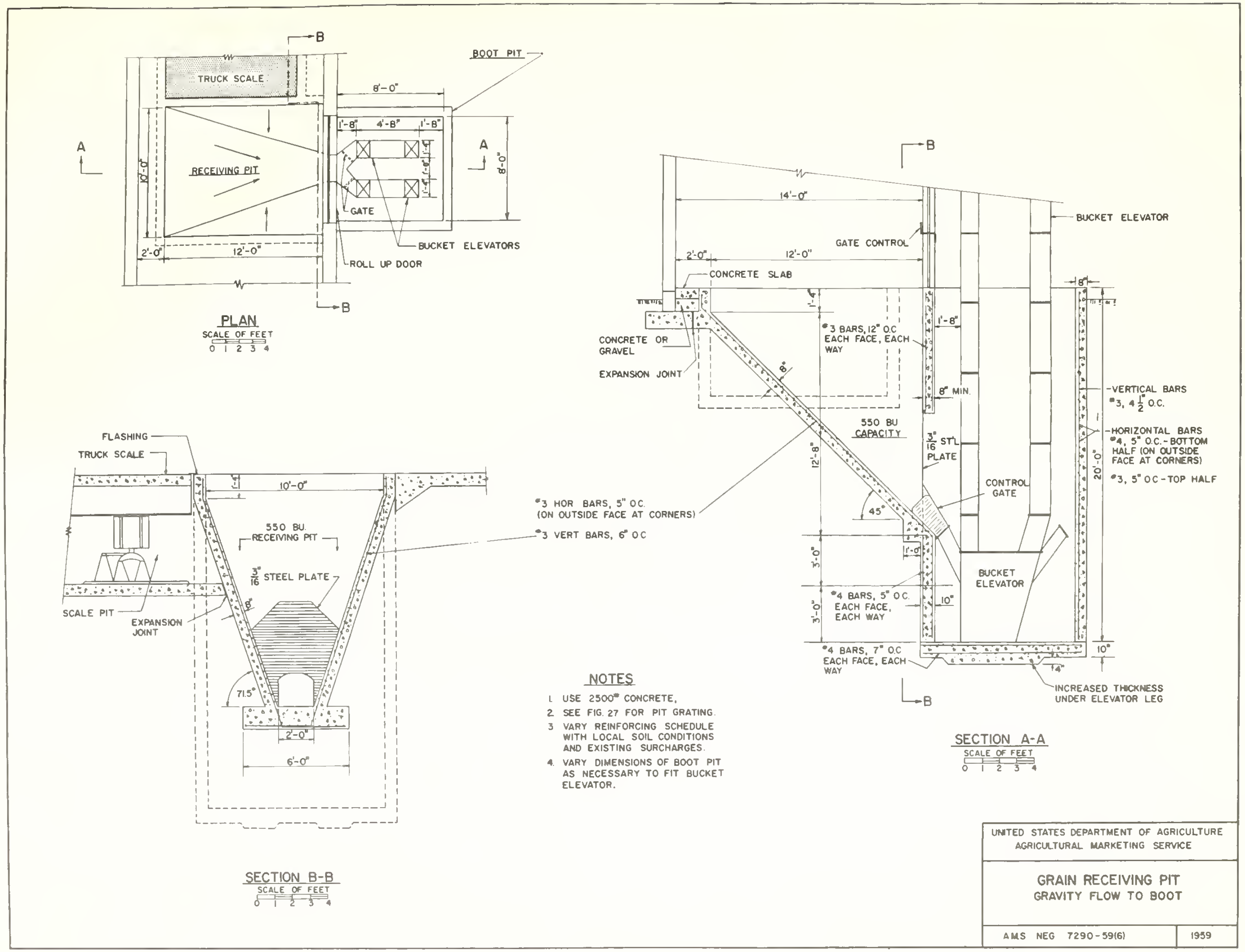
Figure 27.


PLAN
SCALE OF FEET
TRUCK SCALE
RECEIVING PIT
BOOT PIT
GATE
BUCKET ELEVATORS
ROLL UP DOOR
8'-0"
1'-8" 4'-8" 1'-8"
10'-0"
2'-0"
12'-0"
SECTION A-A
BUCKET ELEVATOR
GATE CONTROL
CONCRETE SLAB
CONCRETE OR GRAVEL
EXPANSION JOINT
14'-0"
12'-0"
2'-0"
#3 BARS, 12" O.C. EACH FACE, EACH WAY
8" MIN.
550 BU CAPACITY
3/16 STL PLATE
CONTROL GATE
BUCKET ELEVATOR
45°
#4 BARS, 5" O.C. EACH FACE, EACH WAY
#4 BARS, 7" O.C. EACH FACE, EACH WAY
-VERTICAL BARS #3, 4 1/2" O.C.
-HORIZONTAL BARS #4, 5" O.C.-BOTTOM HALF (ON OUTSIDE FACE AT CORNERS)
#3, 5" O.C.-TOP HALF
20'-0"
INCREASED THICKNESS UNDER ELEVATOR LEG
SECTION B-B
FLASHING
TRUCK SCALE
SCALE PIT
EXPANSION JOINT
550 BU. RECEIVING PIT
3/16" STEEL PLATE
10'-0"
71.5°
2'-0"
6'-0"
#3 HOR BARS, 5" O.C. (ON OUTSIDE FACE AT CORNERS)
#3 VERT BARS, 6" O.C.
NOTES
1. USE 2500# CONCRETE,
2. SEE FIG. 27 FOR PIT GRATING.
3. VARY REINFORCING SCHEDULE WITH LOCAL SOIL CONDITIONS AND EXISTING SURCHARGES.
4. VARY DIMENSIONS OF BOOT PIT AS NECESSARY TO FIT BUCKET ELEVATOR.
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GRAIN RECEIVING PIT
GRAVITY FLOW TO BOOT
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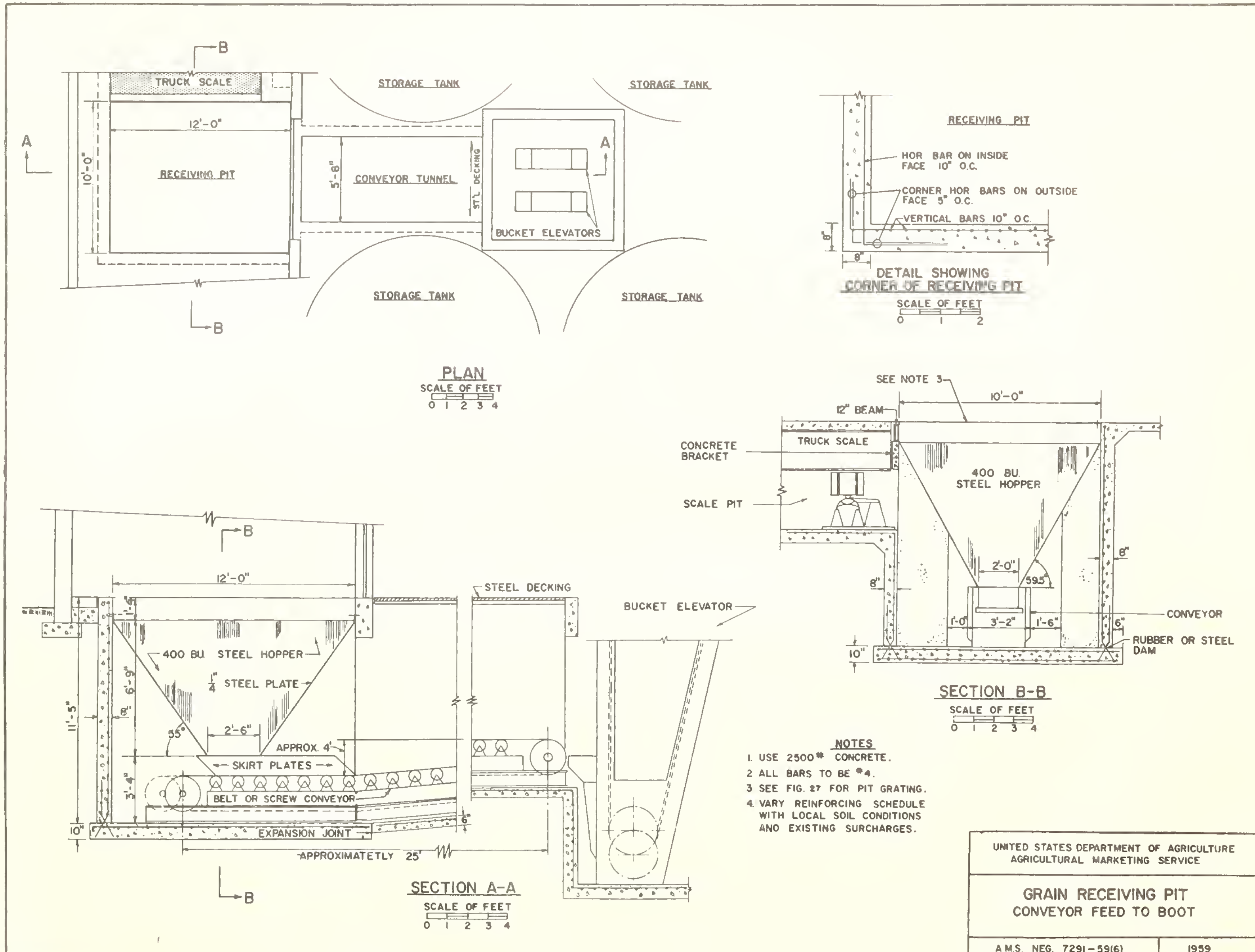
Figure 28.


TRUCK SCALE
12'-0"
10'-0"
RECEIVING PIT
5'-8"
CONVEYOR TUNNEL
ST'L DECKING
BUCKET ELEVATORS
STORAGE TANK
STORAGE TANK
STORAGE TANK
STORAGE TANK
PLAN
SCALE OF FEET
0 1 2 3 4
RECEIVING PIT
HOR BAR ON INSIDE FACE 10" O.C.
CORNER HOR BARS ON OUTSIDE FACE 5" O.C.
VERTICAL BARS 10" O.C.
8"
8"
DETAIL SHOWING CORNER OF RECEIVING PIT
SCALE OF FEET
0 1 2
SEE NOTE 3
10'-0"
12" BEAM
CONCRETE BRACKET
TRUCK SCALE
400 BU. STEEL HOPPER
SCALE PIT
2'-0"
59.5°
8"
8"
CONVEYOR
1'-0"
3'-2"
1'-6"
6"
RUBBER OR STEEL DAM
10"
SECTION B-B
SCALE OF FEET
0 1 2 3 4
12'-0"
STEEL DECKING
BUCKET ELEVATOR
400 BU. STEEL HOPPER
1/4" STEEL PLATE
11'-5"
6'-9"
8"
55°
2'-6"
APPROX. 4'
SKIRT PLATES
3'-4"
BELT OR SCREW CONVEYOR
6"
10"
EXPANSION JOINT
APPROXIMATELY 25'
SECTION A-A
SCALE OF FEET
0 1 2 3 4
NOTES
1. USE 2500# CONCRETE.
2 ALL BARS TO BE #4.
3 SEE FIG. 27 FOR PIT GRATING.
4. VARY REINFORCING SCHEDULE WITH LOCAL SOIL CONDITIONS AND EXISTING SURCHARGES.
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AGRICULTURAL MARKETING SERVICE
GRAIN RECEIVING PIT
CONVEYOR FEED TO BOOT
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Figure 29.

The receiving pit must be provided with a grating or some other type of protection to eliminate the safety hazard of the open pit. The grating must have sufficient structural strength to carry the heavy wheel loads of trucks crossing the grating. The openings in the grating should be small enough so that a man can walk over the grating, yet large enough for the grain to pass through. Figure 27 shows a recommended design for a dump pit grating for an elevator receiving shelled corn or small grain.

Where the receiving pit is in an open building it is recommended that the pit be protected when not in use by screening, sheet metal, or a plastic cover to keep out rodents and insects.

In the Southeast where many plants receive ear corn it often is necessary to have a separate receiving pit for ear corn. It is difficult to build a safe yet practical and economical grating for an ear corn receiving pit. Instead of a grating, a heavy steel plate generally is used to cover the pit opening. This steel cover is raised or lowered by a pulley system but this arrangement is rather slow and unsatisfactory. A grating similar to that shown in figure 27, but with heavier bars spaced about 5 or 6 inches on centers, is suggested for an ear corn receiving pit.

Figures 28 and 29 show two different recommended designs for a receiving pit. In figure 28 the pit hopper is sloped directly to the bucket elevator. This arrangement gives a positive and reliable unloading operation with the grain moving to the tanks, rail cars or larger trucks through the bucket elevator only. In figure 29 the pit hopper is equipped with a belt or screw conveyor which carries the grain to the elevator leg. A further discussion of the relative advantages and disadvantages of these two designs is given under the sections on complete elevator design.

Truck scale.—Figure 30 shows a typical type of truck scales used at a grain elevator. The truck scale consists basically of a platform at floor level, a steel framework supporting the platform, a load supporting lever system, and a counterbalancing and an indicating mechanism. Truck scales are available in a wide range of capacities and sizes.

The elevator owner should consider present requirements as well as future needs, when selecting his truck scales. He should consider not only the size and weight of the largest grain trucks expected, but also the size and weight of other types of trucks which he may be called upon to weigh. For example, in small communities the grain elevator may have the only truck scale and the operator may be called upon to do considerable custom weighing of trucks other than grain trucks. Most elevators require a scale capacity of at least 40 tons. For the designs in this report a 50-ton scale with a 10- by 50-foot platform was selected.

There are several types of weight indicating mechanisms or devices available for truck scales. These include the beam, the dial (both may also have printing and recording attachment), and electronic units for remote recording directly on office machines such as electronic typewriters, adding machines, tape punchers or into a data processing system.

The dial or beam indicating mechanism can be made remote from the rest of the scale by means of an extra leverage system. In general, the dial or beam cannot be located economically more than about 25 feet from its normal position.[7] A dial scale with 10,000-pound by 10-pound graduations and with automatic printing attachment is suggested for small country elevators. The scale should conform to the specifications of the American Railway Engineering Association for the Manufacture and Installation of Four Section Motor Truck Scales.

The scale's platform deck should be strong, durable, and easy to clean. Most existing platform scales at grain elevators have either wood decks or reinforced concrete decks; the reinforced concrete deck is more expensive but is recommended because it creates fewer maintenance problems and is easier to clean. As shown in section B–B of figure 27 a flashing or covering is suggested around

[7] The weight indicating mechanism may be located up to several hundred feet from the scale by using an electric load cell in conjunction with the scale's steelyard.

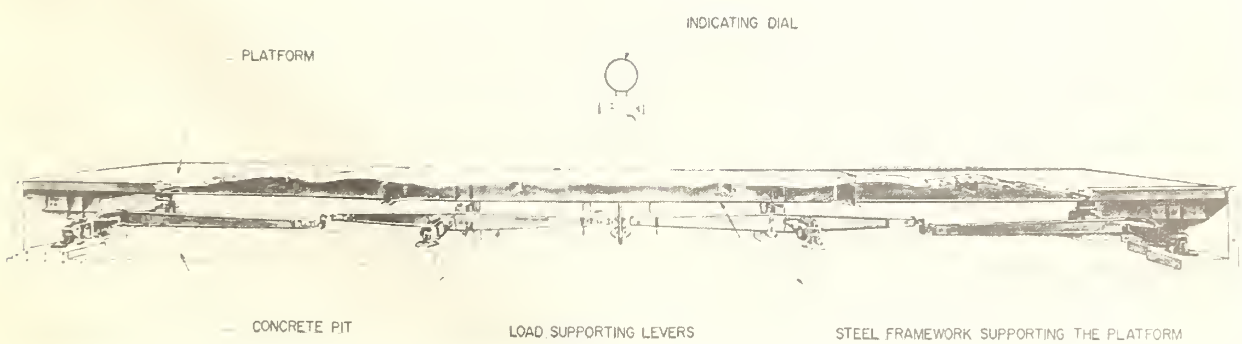


Figure 30.—Truck platform scales.

the edge of the platform near the receiving pit to prevent grain leakage into the scale pit. It is important that this covering shall not restrict the lateral motion of the scale.

Building or shelter.—Careful consideration should be given to the design of the structure for housing the grain receiving pit, truck scales, and truck lift. The building should be wide enough for large trailer trucks, with aisles on either side of the truck; also, it must be high enough to provide clearance when hoisting trucks for dumping. Although it is desirable that the building cover both the receiving pit and scale it is essential that only the pit be completely protected from the weather. There should be a minimum of ledges and crevices where grain and dust can accumulate and ample ventilation to reduce the dust problem. Noise must be considered especially when the office is adjacent to the receiving unit (see page 24).

Two recommended building designs representing different types of construction are illustrated in figures 31 and 32. The first design (fig. 31) shows a steel frame structure covered with sheet metal siding and roofing and steel rigid frames 12 feet on center. Special shaped steel girts and a special molding around the base of the structural columns prevent dust accumulation and facilitates cleaning. Glass-fiber, plastic panels were used in the roof to provide natural lighting. The building has no doors, but canopies are provided over the entrance to provide extra protection from the weather. The building is 14 feet, 8 inches wide, 72 feet, 6 inches long and 16 feet high at the eaves. The estimated construction cost of the building, excluding floors, truck scales, truck hoist, and receiving pit was $3,500, or about $3.30 per square foot of floor area for the Atlanta, Ga., area and for the first quarter of 1959.

The second design (fig. 32) illustrates a more permanent type of construction. The walls are built of 12-inch, concrete blocks with poured concrete or brick pilasters. The roof construction is of precast, "tee" or channel shaped members covered with built-up roofing. The building is provided with metal rolling doors, and is 16 feet wide, 66 feet, 4 inches long, and 16 feet high at the eaves. The estimated construction cost for the building, excluding floor construction, truck scales, truck hoist and dump pit, is $6,500, or about $6.10 per square foot of floor area.

Office Unit

In the small country elevator office, duties include: Recording the weights of truck loads of grain; testing and grading grain samples; keeping records of the enterprise; computing and analyzing sales, costs, and other figures; filing and storing records; meeting and communicating with customers and others. The space and equipment required for these duties are considered as the Office Unit.

Shortcomings in Existing Office Units

Several shortcomings were noted in many of the office units of the elevators studied. Many offices were overcrowded, many had poor working conditions, substandard lighting, heating and ventilation, many had inadequate toilet facilities, and some were not properly insulated or sealed against dust and noise. Construction material used for the floors, walls, and ceiling of the offices were often difficult to keep clean and in repair. Windows often were too small or not located to give the superintendent the necessary view of the various plant operations.

Recommendations and Improved Designs for the Office Unit

The following discussions provides some general principles or guides for planning and designing an improved office unit for a small country elevator. A specific improved office unit design is shown in figure 37 to illustrate these principles.

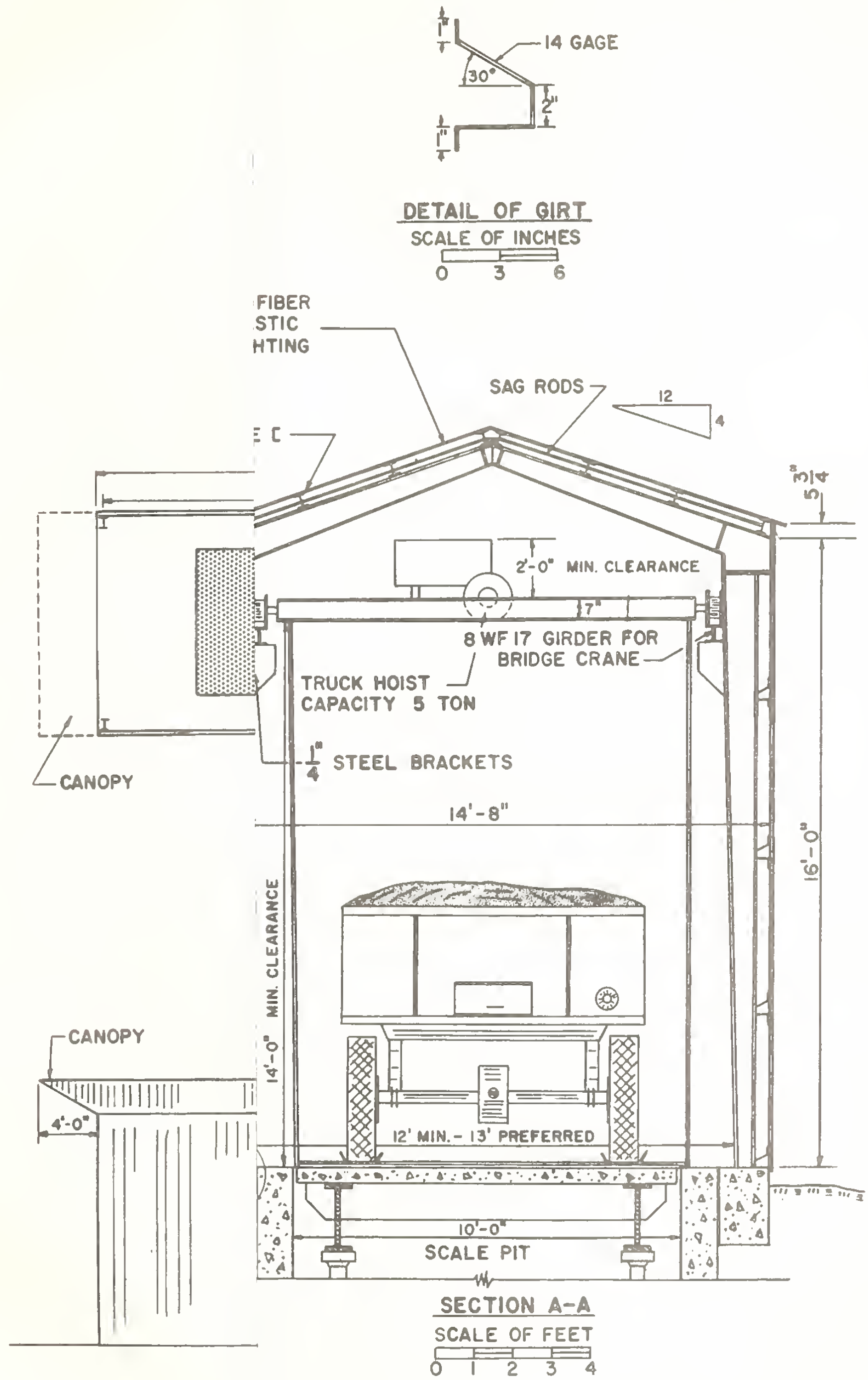
Office layout.—To provide an efficient office arrangement the following basic layout principles should be considered:

1. Plan the layout around the functions to be performed.
2. Use symmetry in the layout; avoid offsets and irregular arrangements.
3. Provide for smooth flow of work through the office; avoid backtracking and crisscrossing.
4. Put files, testing equipment, and other frequently used equipment near the workers who use them.
5. Provide for flexibility; use nonload bearing partitions or movable metal partitions.
6. Provide for expansion.
7. Provide adequate area for the reception of visitors and customers.
8. Provide convenient and adequate toilet facilities.
9. Use functional furniture with adequate and efficiently arranged shelves, drawers and working surfaces.

Although many of the plants visited did not have adequate toilet facilities many State and local regulations specify modern sanitation facilities for the workers. Modern, larger elevators generally provide locker and shower facilities for their employees.

Figure 33 shows a suggested layout for an office unit combined with the receiving unit. The layout provides: (1) An area for the reception of customers and visitors, (2) an area for general office duties including truck weighing, grain testing and miscellaneous work, (3) a private office for the manager, (4) toilet facilities for both plant and office personnel, and (5) a small utility room.

This office layout provides a view of approaching grain trucks and easy access to the scales and receiving pit. And, except during peak seasons,



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STEEL FRAME BUILDING
FOR RECEIVING UNIT

A.M.S. NEG. 7293-59(6) | 1959

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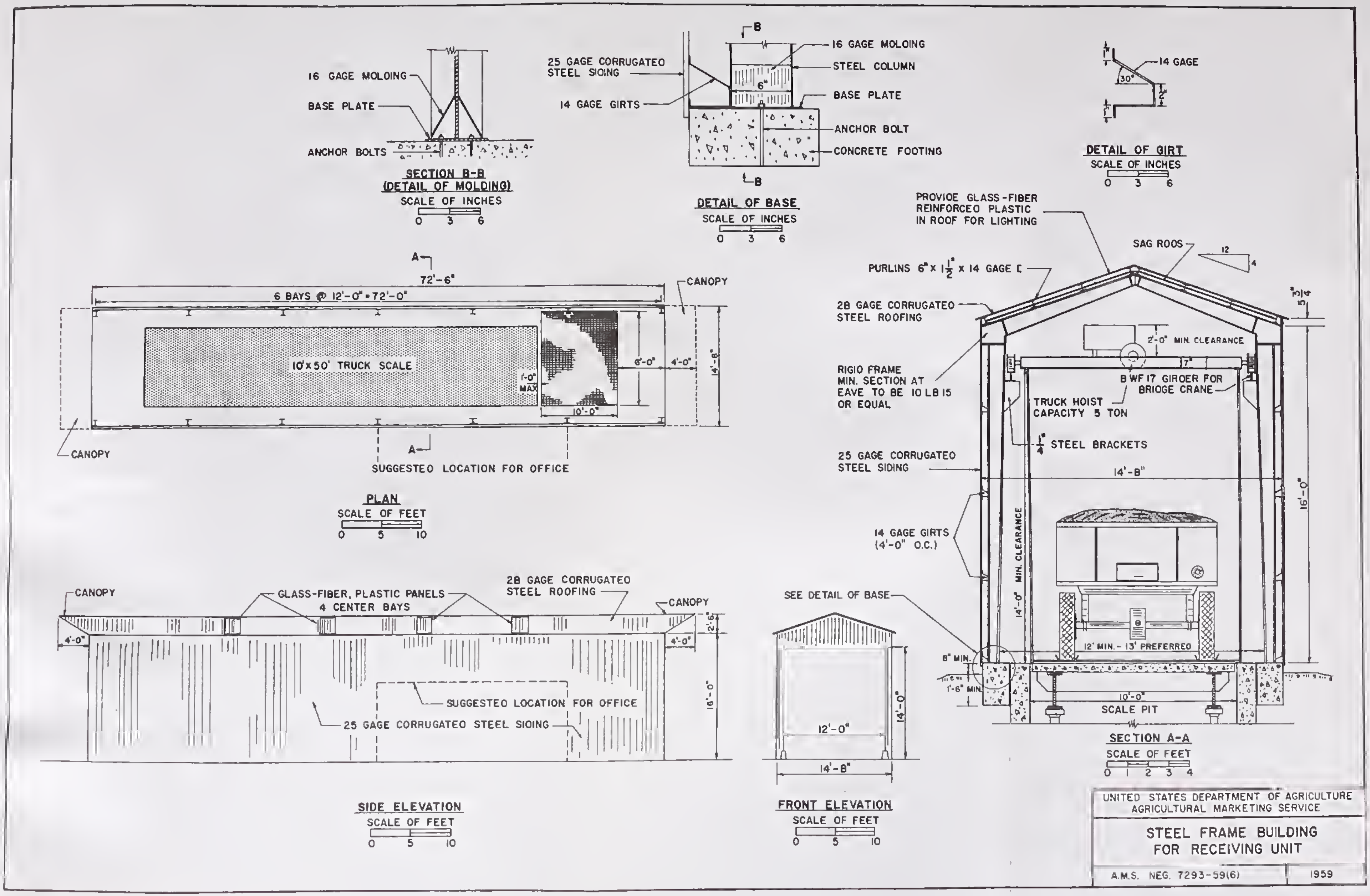

Figure 31.

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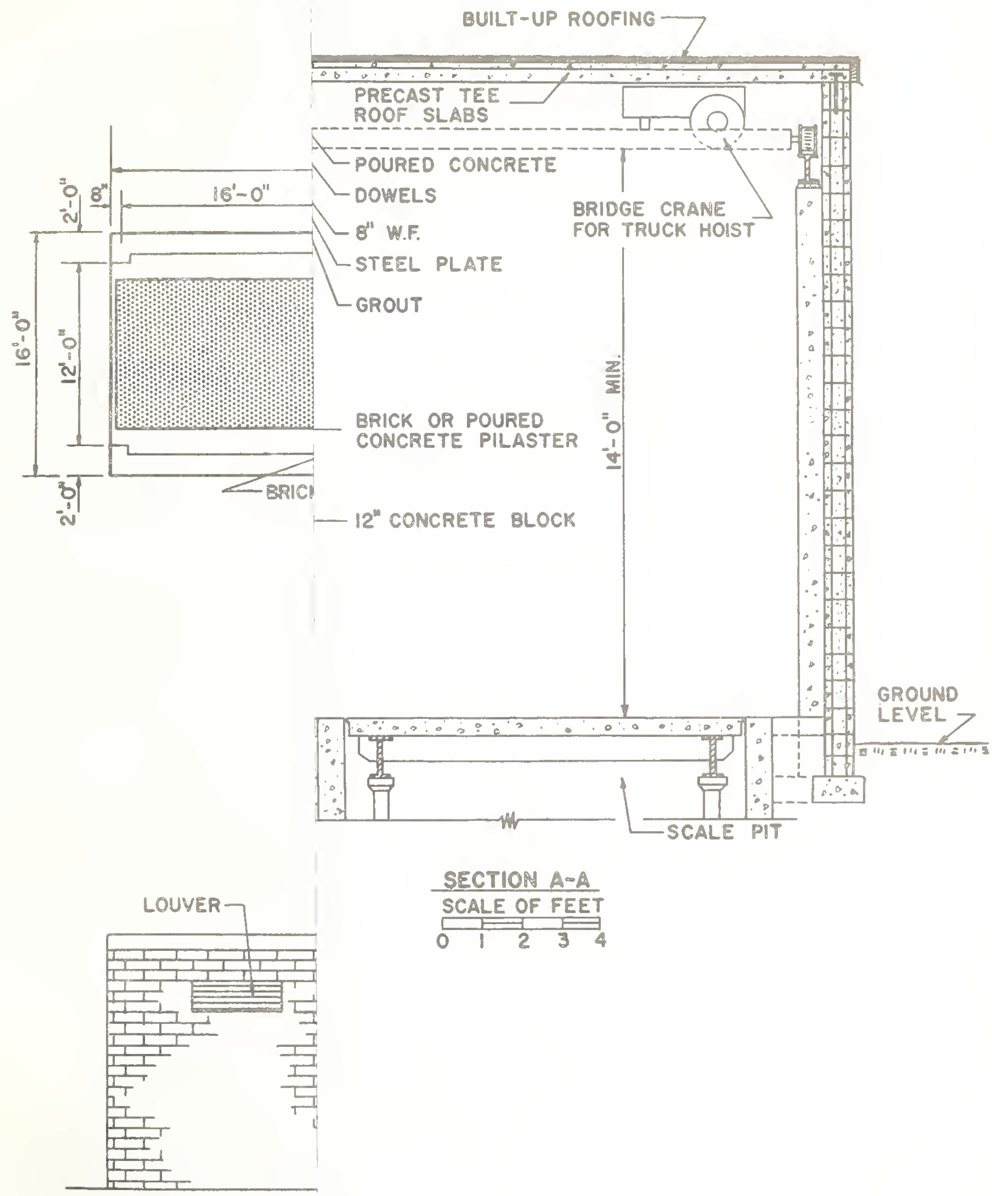

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CONCRETE BLOCK BUILDING
FOR RECEIVING UNIT

A.M.S. NEG. 7294-59(6) | 1959

542944 O - 60 (Faces p. 32) No. 2

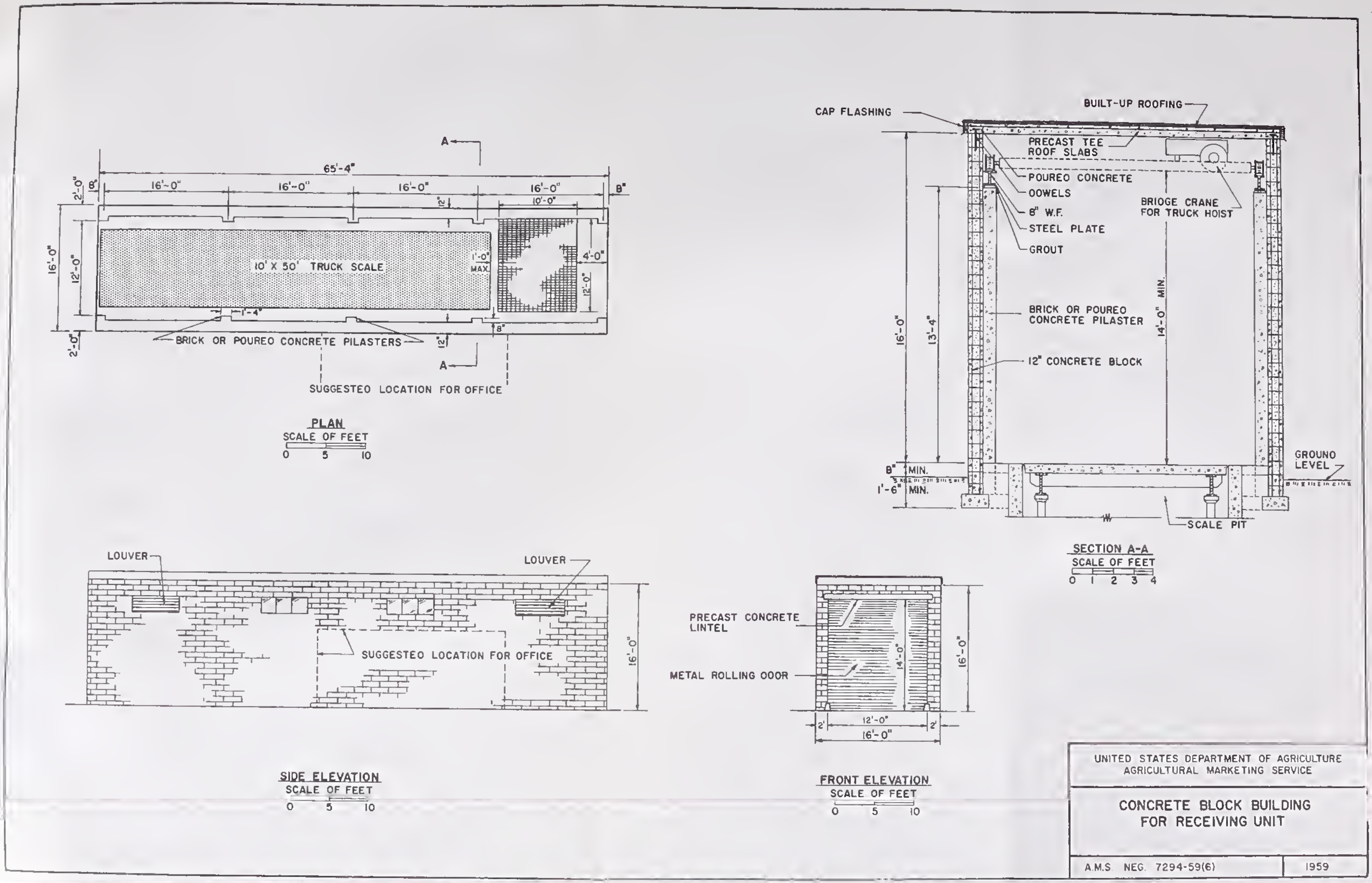

Figure 32.

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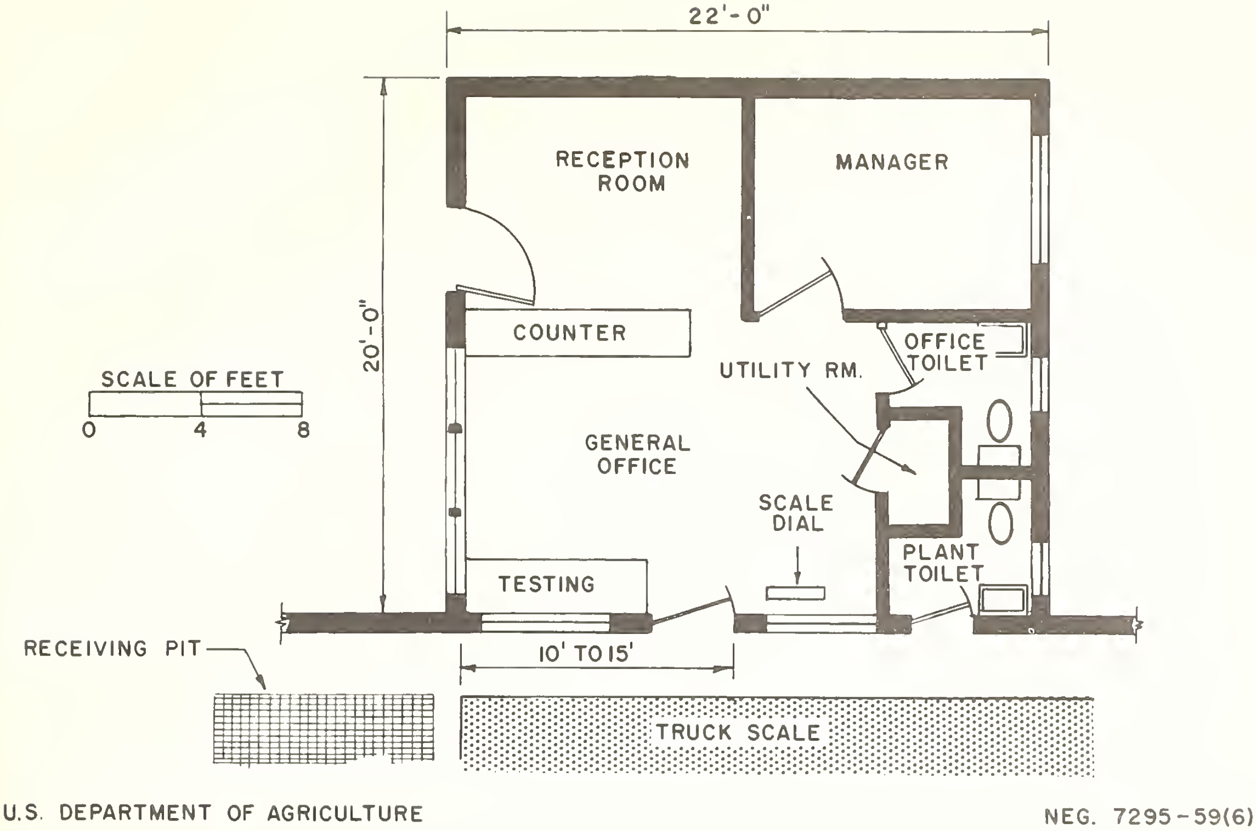


Figure 33.—Layout of office unit where office and receiving units are connected.

one man should be able to weigh, sample, test, and unload. This layout is adequate for most small country elevators; those doing side-line merchandising may require more space.

The private office for the manager provides space for confidential transactions and a quiet area for concentration. The private office, however, hinders the flexible arrangement of the whole office area, as well as complicating heating, ventilating, and lighting designs. A desk unit with built in shelves, cabinets, and partitions is a substitute for the private office which some operators will want to consider (fig. 34).

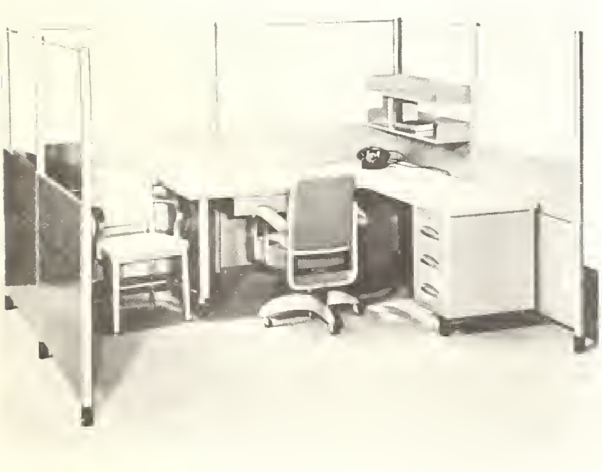


Figure 34.—Desk unit with built-in partitions.

The layout in figure 33, however, does not provide for passage of customers and others between the reception area and the receiving unit without going through the general office area. An alternate layout (fig. 35), provides for such movement with the general office area and the manager's area separated by the reception area; this may be a disadvantage in some cases.

Where the office unit is connected with the receiving unit, there is the question of where the office should be located in relation to the truck scale and receiving pit. In both layouts (figs. 33 and 35) the office is shown near one end of the truck scale and near the receiving pit. This gives the operator a good view and control of loaded grain trucks as they approach the scales. Also, one-man operation requires considerable movement between the weight indicator (dial) and the receiving pit and this arragnement puts these close together. However, this arrangement requires the extra cost of moving the dial away from its normal position at the center of the platform scale; also, the dial is not as easily seen in this position by the truck drivers. In both layouts the office and receiving unit build-

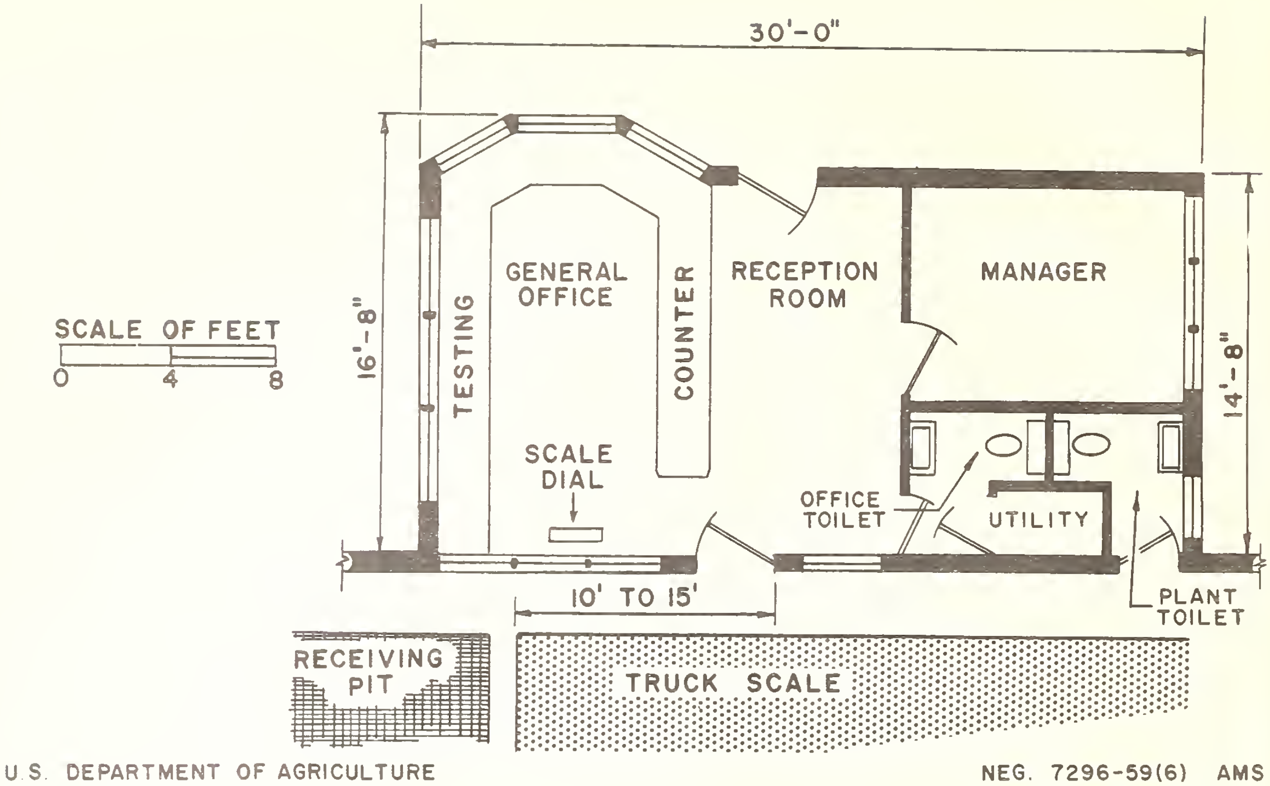


Figure 35.—Alternate layout of office unit where office and receiving units are connected.

ing would be at ground level. If grain samples are to be collected by probing, a small portable platform about 30 inches high can be used to give the operator easy access to the bed of the grain truck.

The suggested layout in figure 36 shows the office unit and receiving unit separated. The large bay windows give the scaleman a good view of trucks moving both on and off the scale. The office floor is elevated about 42 inches above the level of the platform scale to make it easy for the scaleman to obtain probe samples from the truck. The testing equipment is located near the weight indicating dial so the scaleman can perform the several operations of weighing and testing grain with a minimum of movement while in one position. Where a two-man weighing and testing crew is used at times, the testing bench should be on casters so that it can be rolled out on the platform.

The office building.—Figure 37, A and B, shows a recommended office building design of concrete block based on the layout shown in figure 33. This type of building is also adaptable to the layouts in figures 35 and 36. There are many other types of construction suitable for an office, and the elevator operator can select one to meet his particular requirements.

The estimated construction cost for the office building shown in figure 37, including heating and electrical work, but excluding furniture, was roughly $6,200 or $14.10 per square foot of floor area.

As shown in figure 37 a concrete slab on grade with asphalt tile flooring was selected for the floor construction because of its low construction and maintenance cost. All interior partitions are 4-inch nonload bearing concrete masonry units selected so that partitions can be removed or rearranged in any future changes or expansions. Forty-inch high glazed wainscote was selected for most of the interior partitions to provide for easy housecleaning; this was accomplished by using concrete masonry units which have a thermo-set ⅛-inch glazed facing.[8]

The exterior walls are 8-inch, load-bearing, concrete masonry units with the exception of one wall which is non-load bearing. The roof is constructed of precast concrete channel-shaped slabs or precast concrete joists and concrete roof slab, covered with a vapor seal, rigid insulation, and built-up roofing. The underside of the concrete roof construction is to be painted a light color and left exposed to serve as the ceiling of the office. This roof design represents low cost, fireproof and reasonably maintenance-free construction. Metal door frames and flush wood doors are used. The lower 10 inches of the wood doors

[8] Masonry walls can also be painted with an epoxy (plastic) coating to give the walls a glazed finish.

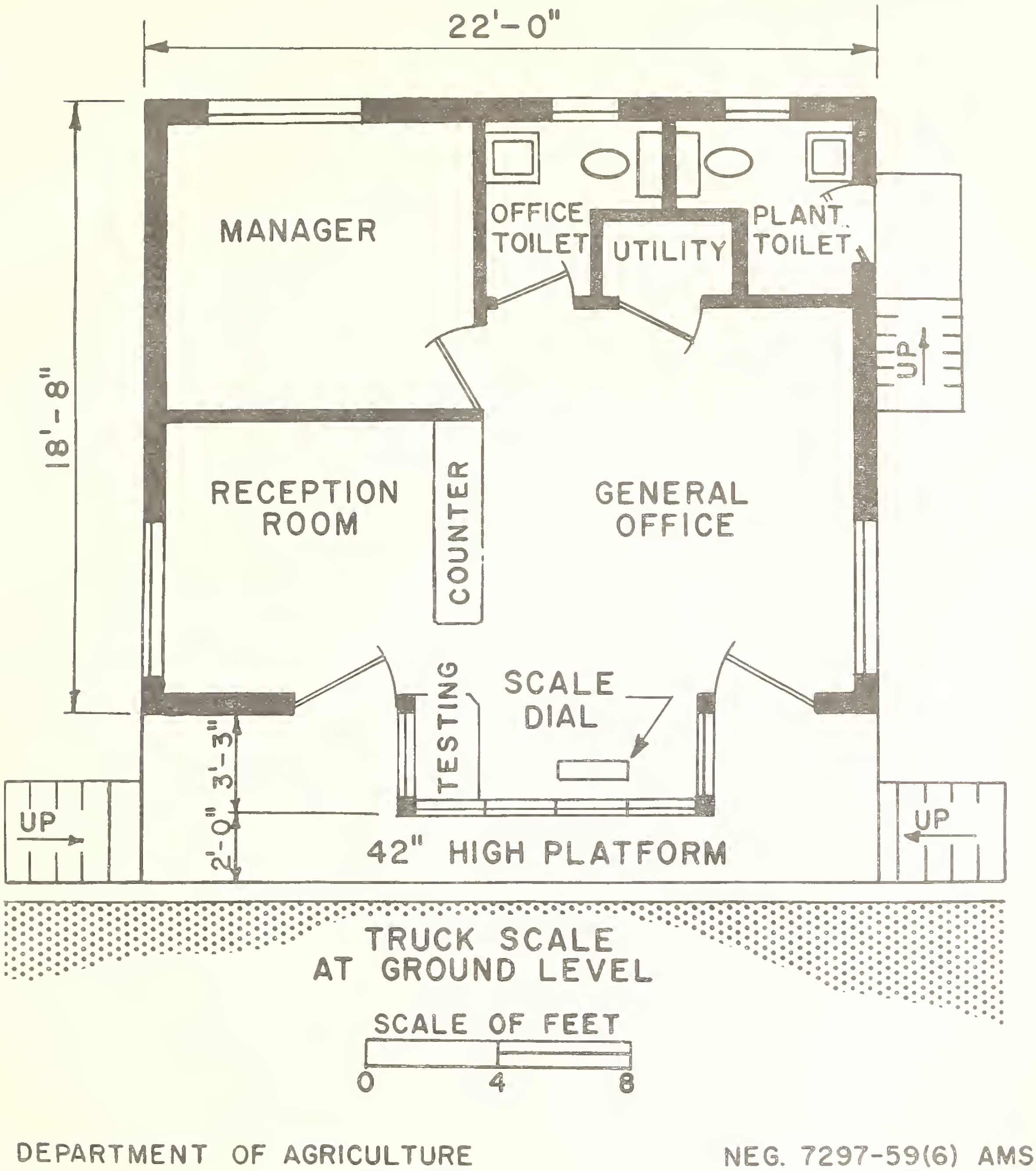


Figure 36.—Layout of office where office is separate from receiving unit.

are protected with 24-gage sheet aluminum for rodent proof constructions. A double acting, hollow, metal door is used between the general office area and the receiving unit. All glazing between the office unit and the receiving unit is to be 1/4-inch wired glass.

A minimum of from 30- to 40-foot candles of lighting at working surfaces should be considered for the office unit. Latest recommendations of the Illuminating Engineering Society, however, recommend lighting levels of as high as 100-foot candles for regular office work. To reduce glare, an indirect or semi-direct lighting fixture with highly reflective ceiling and wall surfaces is suggested.

Sufficient electrical wiring should be provided to meet possible future demands of additional lighting, business machines, testing equipment, and other similar needs. Plug-in strip molding might be used above benches and work tables. Electrical raceways in the floor are suggested for flexibility and future expansion. All wiring and

equipment should be installed in accordance with the local codes and applicable sections of the National Electrical Code.

No attempt was made to design the heating system for the office unit; this will depend on local climatic conditions and the type of fuel or power available. Heating systems should be installed in accordance with the local codes and approved practices of the trade.

Natural ventilation is accomplished by projected steel window units. But many operators in the South will want to consider air conditioning to improve working conditions in the office.

Corn Shelling Unit

Considerable ear corn continued to move to market in the Southeast through 1959. However, in many areas—for example, the eastern counties of North Carolina—more picker-shellers are being used each year with less ear corn moving to market. Therefore, storage operators planning facilities for handling ear corn should consider not only present requirements but also trends for their area.

The corn shelling unit contains the dump pit for receiving ear corn, a conveyor for moving the ear corn to the corn sheller, and the sheller itself. A small elevator leg or horizontal conveyor is necessary to move the shelled corn from the sheller.

Disposal of cobs and shucks from the sheller is an ever existing problem. In some plants studied the cobs and shucks were ground in a hammer mill and the ground material stored in bags for future sale; this required considerable storage buildings and labor. In other plants the cobs and shucks were blown into a pile where they were burned; this created a fire hazard and in some cases caused considerable smoke. In other plants the shucks were baled and the cobs burned. These operations required additional equipment—a hay baler—and labor to handle the baling operation. In still other plants the cobs and shucks were hauled to a disposal area, requiring a truck and part of a man's time to operate the truck.

In most plants studied the dump pits were too small to handle ear corn efficiently. The pits usually were uncovered and were a safety hazard. When the truck or trailer endgate was removed corn would fill the pit and then pile up all around the pit (fig. 38). This required considerable hand shoveling to clean up after each load. See discussion of receiving pits, page 25.

BN-9450-X

Figure 38.—Considerable cleanup is required after unloading into this small receiving pit.

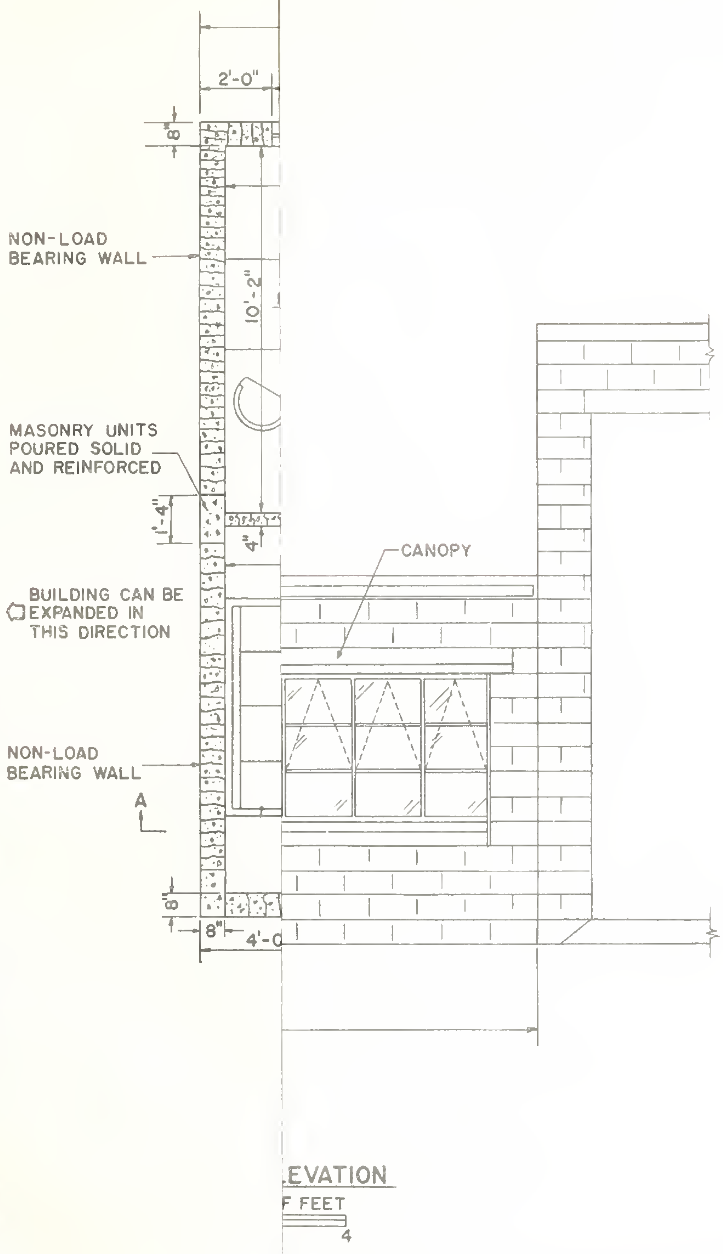
Recommendations and Improved Designs

A corn sheller, with cleaning attachment, with a capacity of 800 to 1,000 bushels per hour of machine-picked or machine-snapped corn was selected for the designs shown in this report. Some corn shellers are more suitable than others for shelling Southern types of corn. Before buying a sheller, investigate thoroughly the sheller specifications and capacities.

It is recommended that, to provide a uniform and steady flow of ear corn to the sheller, a control device be installed that will prevent the sheller from being overloaded. Corn crushers are sometimes used just ahead of the sheller to break up the ears of corn and assist the shelling operation. However, no corn crushers were being used in any of the plants studied.

Recommended designs for corn shelling units are described in figures 39 and 40.

Figure 39 shows a dump pit with a capacity of about 300 bushels; large enough to hold the load of corn from an ordinary farm truck or trailer. See discussion on receiving pits on page 25. The sheller is to be located at ground level to provide for easy maintenance and cleaning up around the sheller. A 16-inch diameter screw conveyor, built into the pit, conveys the ear corn from the pit to the sheller. The conveyor can be driven with a variable speed drive for control of the amount of ear corn going to the sheller. A front end truck lift provides for easy unloading into the dump pit. Corn is to be removed from the sheller by a bucket elevator high enough to permit gravity flow into the main storage leg or into a truck; or



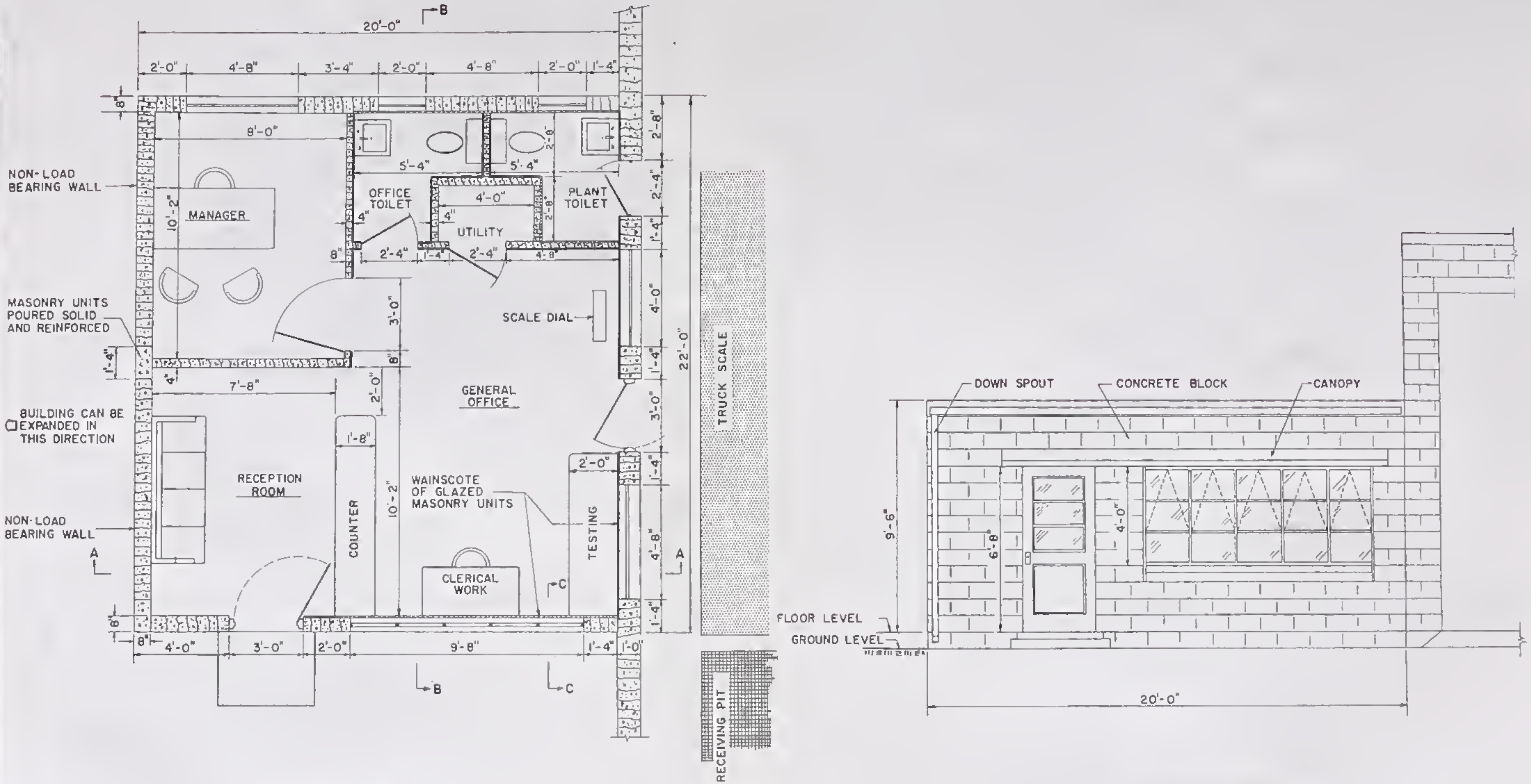
SEE FIG. 37-B FOR SECTIONAL VIEWS.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

OFFICE BUILDING
PLAN & ELEVATION

AMS NEG. 7298-59(6) | 1959

542944 O - 60 (Faces p. 36) No. 1



FLOOR PLAN

SCALE OF FEET

0 2 4

FRONT ELEVATION

SCALE OF FEET

0 2 4

SEE FIG. 37-B FOR SECTIONAL VIEWS.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

OFFICE BUILDING
PLAN & ELEVATION

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Figure 37 A

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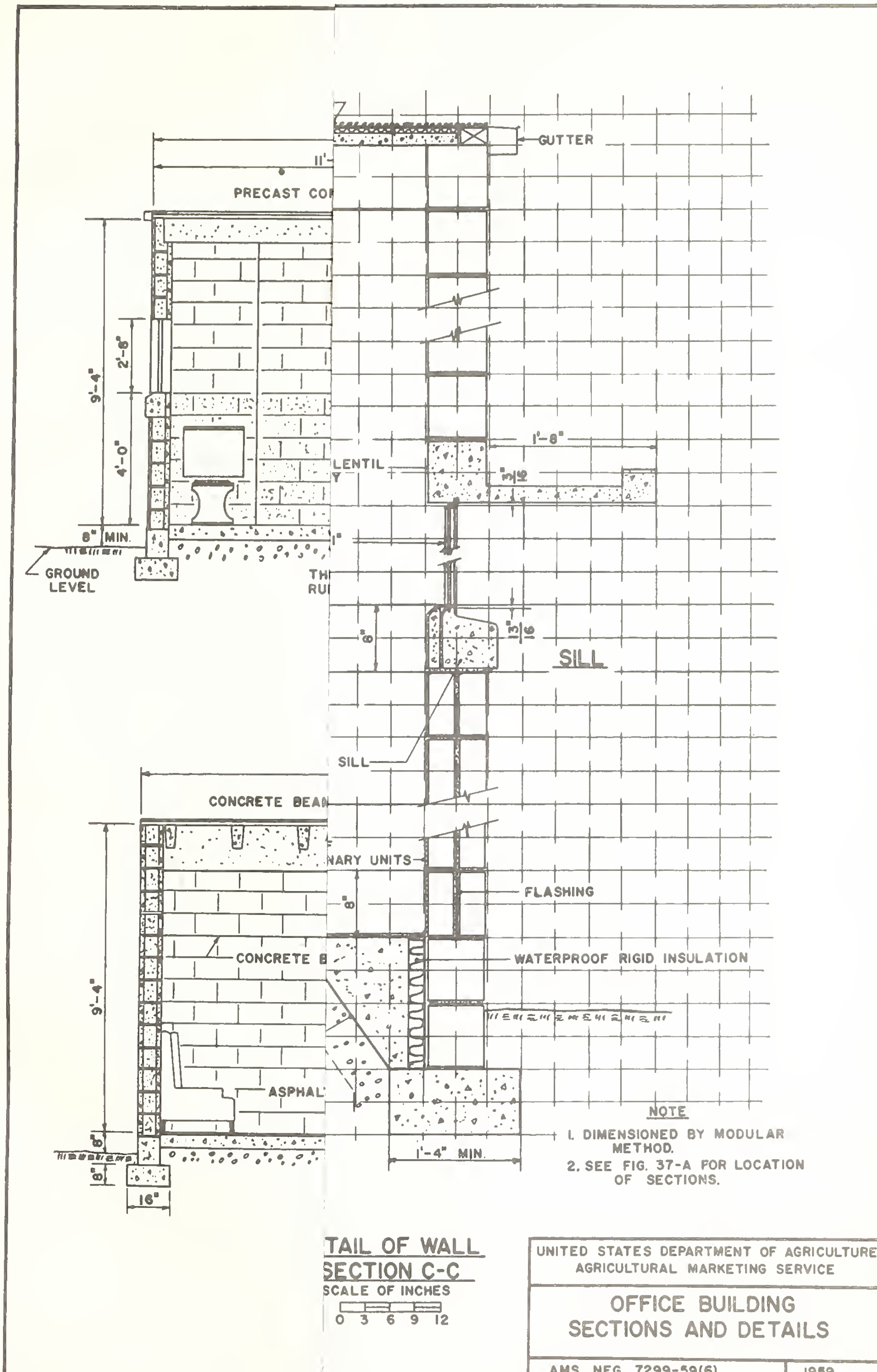


UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

OFFICE BUILDING
SECTIONS AND DETAILS

AMS NEG. 7299-59(6) | 1959

542944 O - 60 (Faces p. 36) No. 2

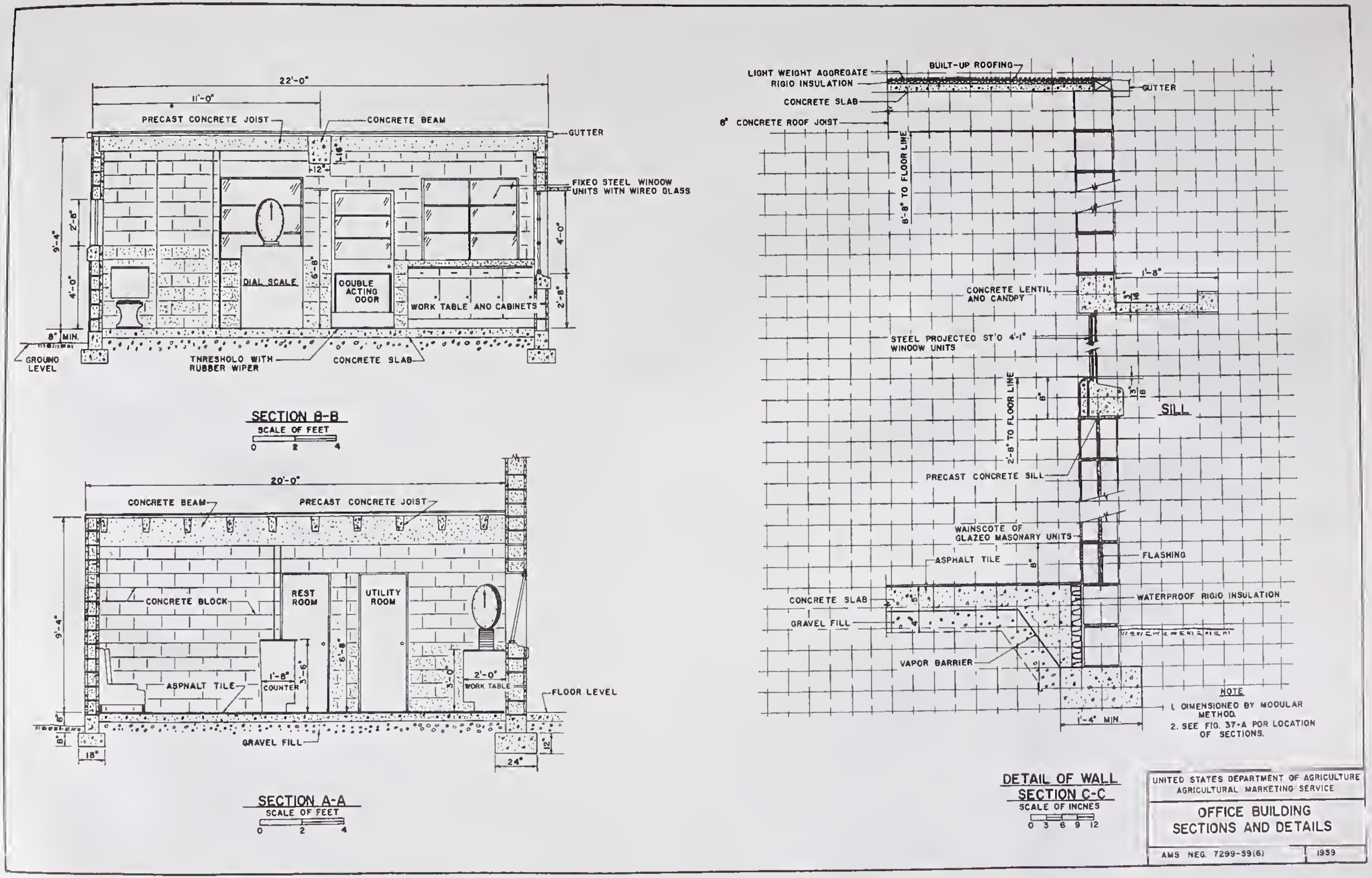

22'-0"
11'-0"
PRECAST CONCRETE JOIST
CONCRETE BEAM
GUTTER
FIXED STEEL WINDOW UNITS WITH WIRED GLASS
DIAL SCALE
DOUBLE ACTING DOOR
WORK TABLE AND CABINETS
8" MIN.
GROUND LEVEL
THRESHOLD WITH RUBBER WIPER
CONCRETE SLAB
SECTION B-B
SCALE OF FEET
20'-0"
CONCRETE BEAM
PRECAST CONCRETE JOIST
CONCRETE BLOCK
REST ROOM
UTILITY ROOM
ASPHALT TILE
COUNTER
WORK TABLE
FLOOR LEVEL
GRAVEL FILL
SECTION A-A
SCALE OF FEET
LIGHT WEIGHT AGGREGATE
RIGID INSULATION
BUILT-UP ROOFING
CONCRETE SLAB
8" CONCRETE ROOF JOIST
GUTTER
8'-8" TO FLOOR LINE
CONCRETE LENTIL AND CANOPY
STEEL PROJECTED ST'D 4'-1" WINDOW UNITS
2'-8" TO FLOOR LINE
SILL
PRECAST CONCRETE SILL
WAINSCOTE OF GLAZED MASONARY UNITS
ASPHALT TILE
FLASHING
CONCRETE SLAB
WATERPROOF RIGID INSULATION
GRAVEL FILL
VAPOR BARRIER
1'-4" MIN.
NOTE
1. DIMENSIONED BY MODULAR METHOD.
2. SEE FIG. 37-A FOR LOCATION OF SECTIONS.
DETAIL OF WALL SECTION C-C
SCALE OF INCHES
UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE
OFFICE BUILDING SECTIONS AND DETAILS
AMS NEG. 7299-59(6)
1959

Figure 37 B.

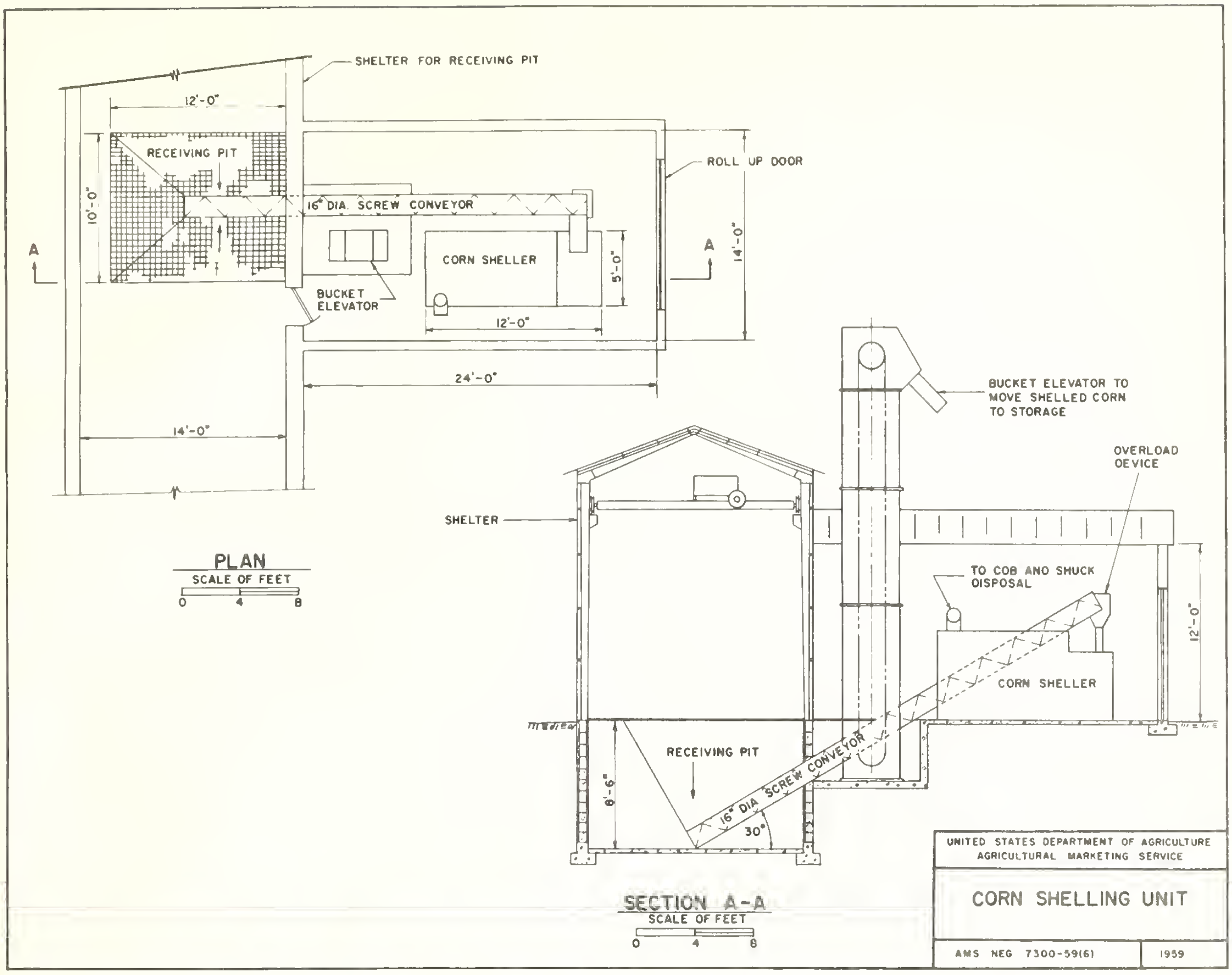


Figure 39.

a horizontal conveyor can be used to move the shelled corn to the main storage leg.

The layout in figure 40 is similar to that in figure 39 except that the cornsheller is located in a pit on the same level with the dump pit. With this arrangement a much shorter conveyor can be used to move the corn to the sheller. The corn is to be elevated from the sheller pit by a bucket elevator and moved to the main leg by gravity or by a horizontal conveyor.

Buildings

The layout in figure 40 requires more excavation and pit wall than the layout in figure 39. The added cost for the excavation and wall, however, is offset by the cost of the longer conveyors required in the other layout (fig. 39). The building material used for housing the shelling unit would be the same type as that used for the receiving unit.

Grain Drying Unit

In some areas, corn harvest is becoming earlier because of the increased use of picker-shellers. Early harvest benefits producers along the Coastal Plains of the Southeast where heavy rains and storms often occur during the normal harvest season. But with earlier harvesting, higher moisture corn moves to market and there is greater demand for commercial drying. Therefore, a dryer can be an important piece of equipment in many grain elevators. In planning a new plant or in the remodeling of an existing one, thorough study and consideration is needed to determine if a dryer is feasible and necessary.

The main parts of a grain dryer include a bin or column for holding the grain, a heater unit, the necessary conveying equipment to move the wet grain into the dryer and the dry grain away from it, and some mechanical arrangement to regulate the flow of grain through the dryer. The location of the drying unit and its connection to the storage unit are important because of the fire hazards associated with any grain dryer. Grain dryers, to function properly, should be designed and built by reputable manufacturers. They should be installed in accordance with applicable standards.

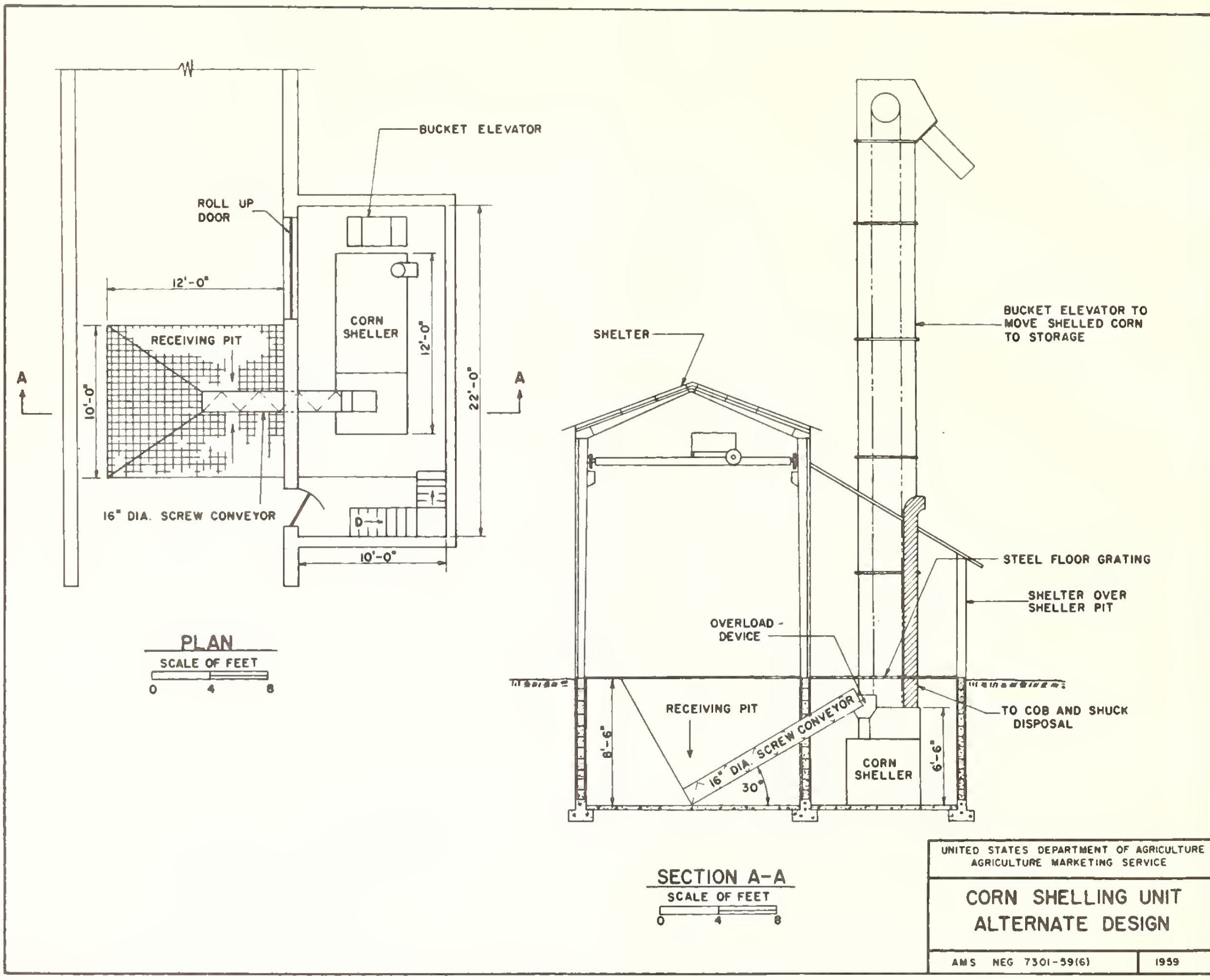


Figure 40.

Dryer capacities are rated in bushels per hour for a specified moisture reduction. The specifications supplied by the manufacturer should be carefully checked to insure obtaining the desired drying capacity. Some plant designers recommend a dryer with sufficient capacity to dry, in 24 hours of continuous operation, the grain handled at an elevator in a normal 10-hour day. Good management is necessary for the successful use of a dryer. High drying temperatures—140° F. and above—can change the chemical composition and nutritive values of grain (*35*).

Most commercial dryers are the continuous-flow type with direct-fired oil or gas burning heater. With this type of heater the products of combustion go directly into the heated air stream and pass through the grain being dried. In a continuous-flow dryer the grain is dried as it flows through the drying section at a regulated rate (fig. 41). Most dryers also have a section (fig. 41) to cool the warm dried grain coming from the drying section. This is desirable as warm grain placed in storage will remain warm for a considerable length of time; such conditions are favorable for insect activity and mold growth.

Holding bins for both wet and dry grain usually are provided. Some designers recommended a bin that will hold enough wet grain for 4 hours of dryer operation. Grain often is moved to this bin by the main bucket elevators of the plant. A smaller bucket elevator generally is installed to move the dried grain to its holding bin.

Development of a Plant for Handling Shelled Corn and Small Grain

The various units previously discussed—receiving unit, office unit, and storage unit—have been combined and modified as necessary to form a complete and integrated plant for receiving, handling, and storing shelled corn and small grain. The plant is a small country grain elevator with a storage capacity of about 32,000 bushels and with the

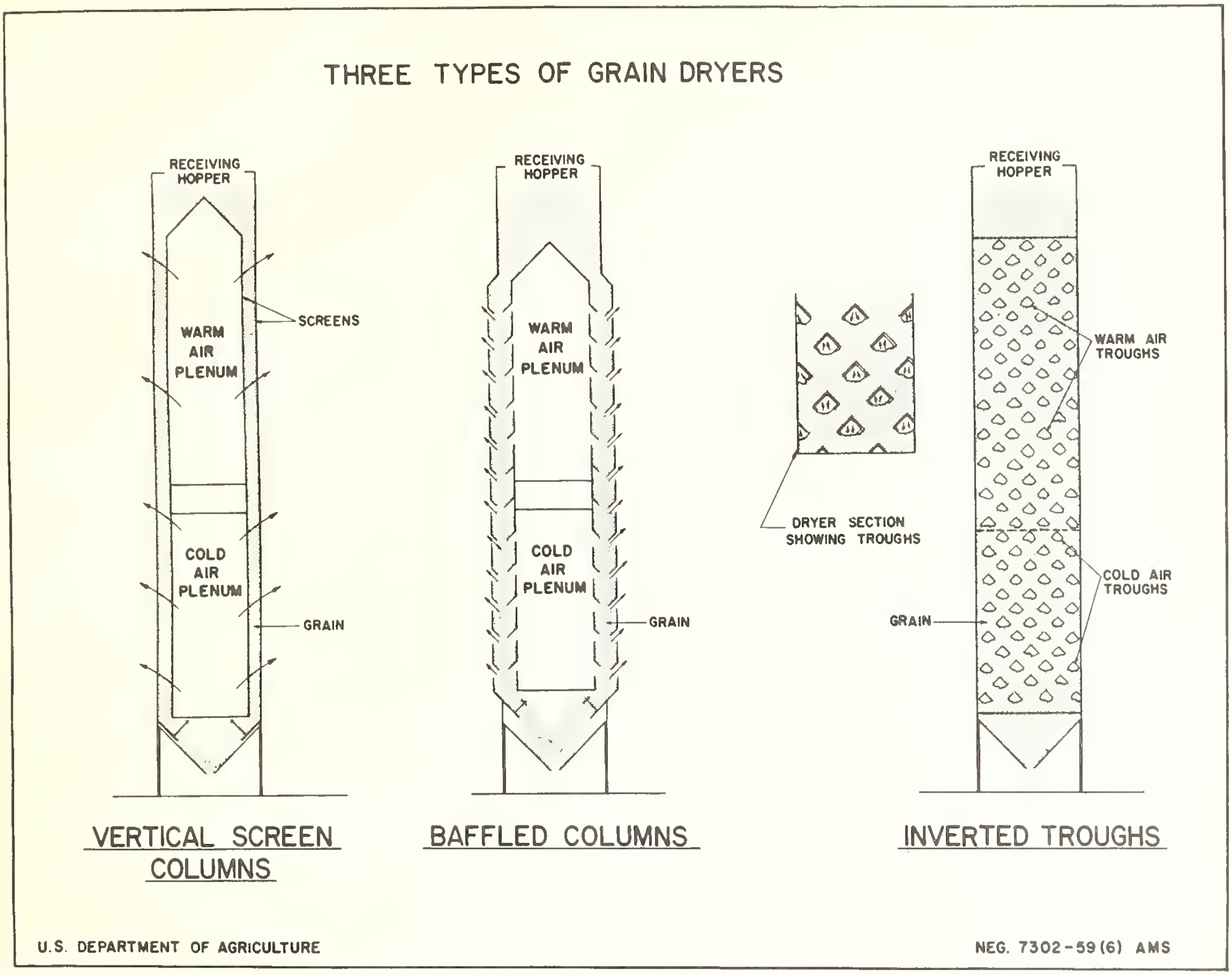


Figure 41.

assumed types of operation as described under the general design assumption, page 3.

Shortcomings in Existing Plants

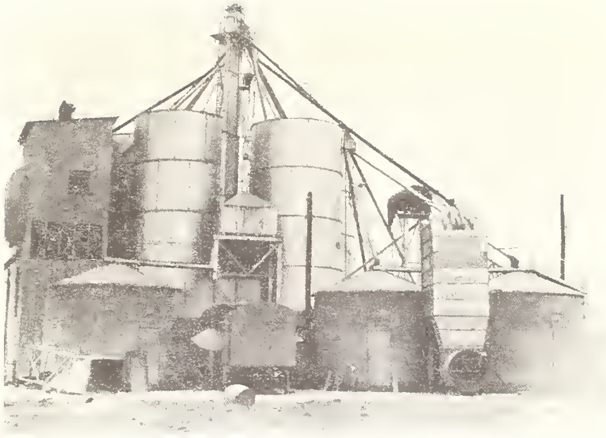
In developing designs for the facility, efforts were made to avoid the shortcomings and defects found in existing elevators studied. Besides the shortcomings previously discussed under the various units, other defects were noted which applied to the plant as a whole.

Many elevators had many short conveyors. As a large part of a conveyor's cost is in its terminal elements (pulleys, motors, and drives) it is advisable, when possible, to use one long conveyor rather than a combination of several short ones. The grain handling machinery and equipment often had too small a handling capacity causing delays, long waiting lines for customers, and bottlenecks in handling operations. Provision for future expansion was often lacking, causing the elevator to grow up in a haphazard manner (fig. 42). The elevator sites were often poorly selected and arranged with inadequate area for truck traffic and parking space and for future expansion.

Recommendations and Improved Designs

Layout and Arrangements

Figure 43 shows a recommended arrangement for a grain elevator receiving shelled corn and small grain. Four circular tanks together with interstitial bins are grouped together to form the storage unit with two 2,000-bushel per hour bucket elevators being used for handling the grain. Grain moves by gravity both from the elevators to the tanks and from the tanks to the elevator boot. The cleaner is located below the interstitial bins about 10 feet above the ground floor level, or it can be at ground level. There should be ample area around the tanks at ground level to check drawoff gates and for general movement through the plant, so the size of the cleaner that can be used is limited. Grain can be received rapidly into the interstitial, or holding bins, dur-



BN-9452-X

Figure 42.—When no plans are made for future expansion plants often grow in a haphazard manner.

ing peak receiving periods and cleaned during slack periods with a low capacity cleaner.

The receiving unit (truck scales included) is located adjacent to the storage tank.[9] A receiving pit similar to the one shown in figure 28 is used for this plant; grain can flow from the trucks into the pit, and directly to the boot of the elevator.

An office unit similar to figure 35 was selected for this layout. The office is located adjacent to the receiving unit, and opposite to the storage tanks. It is located relatively close to the receiving pit so that the operator has a good view and control of loaded grain trucks as they approach the receiving pit (see p. 33 for more discussion on this arrangement). He can easily move from the office and scale dial to the receiving pit to open truck end gates, take grain samples, and clean up around the pit.

This layout (fig. 43), along with other plants shown in this report, was designed basically for a one-man operation. The following are necessary for a successful one-man operation: (1) Locate receiving pit, weight indicating mechanism, testing equipment, and controls for truck hoist close together; (2) provide sufficient lift on truck hoist for gravity unloading of entire truck; (3) encourage the use of easily opened, wide endgates on trucks; (4) use a large receiving pit; (5) study and carefully plan all the workers operations; (6) provide for remote control of machinery and handling equipment; (7) provide sufficient windows and other means to give the operator a clear view and control of both unloading and loading operations; and (8) provide signs or automatic signals to direct truck drivers.

The flow diagram in figure 43, *B* illustrates how grain moves through the plant. The operations involved in handling the grain are: (1) Truck unloading, (2) cleaning, (3) turning, (4) drying, (5) truck loading, and (6) rail car loading. The two main elevator legs, the wet grain holding bin for the dryer, the dryer elevator, and the spout system feeding the main elevator boots provide for flexible handling operations. Most of these operations can be performed simultaneously. Turning of grain "ties up" the distributor, and limits other operations requiring use of the distributor.

There are a few disadvantages to this arrangement. For example, in some areas where the water table is high or where excavation in rock is required, construction of the deep grain receiving pit and other pits may be costly. And, with the rail siding on the same side as the office, expansion of the office unit is limited and noise and dust from the railroad may be disturbing to the office personnel. Also, with the cleaner below the holding bins grain cannot be cleaned on receipt and moved directly to the bins or truck or rail loadouts without being re-elevated.

Both the rail and truck loading facilities are located on the office side of the plant. A bay window in the office gives the operator a good view and control of all loading out operations. Also, storage tanks can be added in three directions in future expansion. No provision was made for weighing out rail shipments.

An arrangement for adding a grain dryer to this layout (fig. 43), has been made. One tank can be divided into wet grain and dry grain bins and a small bucket elevator used to move the grain from the dryer to the dry grain bin.

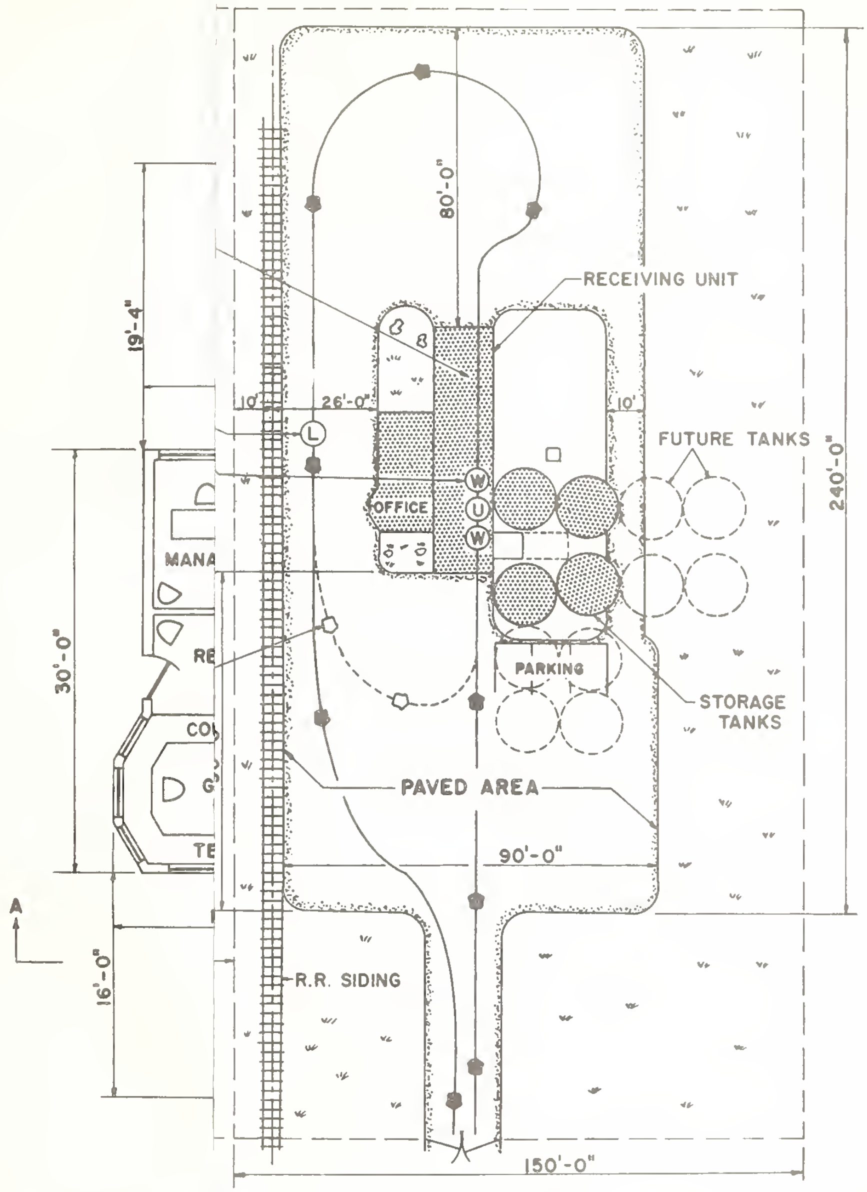
Loaded grain trucks enter the plant site and line up to enter the receiving unit (fig. 43, *A*). The truck then pulls onto the scale with the front wheels resting in the cradle of the truck hoist. With a one-man operation, the operator weighs and unloads the truck; he operates the hoist and opens the end gate; takes a sample of grain, often by cutting the stream of grain as the truck unloads; makes the necessary tests on the grain; and finishes up the unloading by hand if necessary. The empty truck is lowered and weighed and then pulls off of the scale.

Trucks receiving grain from the plant, pull onto the scale and weigh empty. During slack receiving periods, or for small shipments, trucks can be loaded while on the scales. During peak receiving periods the trucks would pull off the scale after being weighed, and load in another location (fig. 43, *A*). After being loaded the trucks return to the scales to weigh loaded. Trucks receiving grain can pull onto the scales in the opposite direction from trucks unloading grain. This provides the truck driver with a better view of the scale dial.

Alternate Arrangement

Figure 44, *A* and *B*, shows an alternate arrangement for handling shelled corn and small grain that is, in general, similar to the arrangement in

[9] See section on the advantages and disadvantages of combining the truck scales with the receiving unit, page 23.



SITE PLAN

SCALE OF FEET

0 10 20 30 40

UNITED STATES DEPARTMENT OF AGRICULTURE
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PLANT HANDLING SHELLED CORN
AND SMALL GRAIN

LAYOUT AND SITE PLAN

AMS NEG. 7303-59(6)	1959

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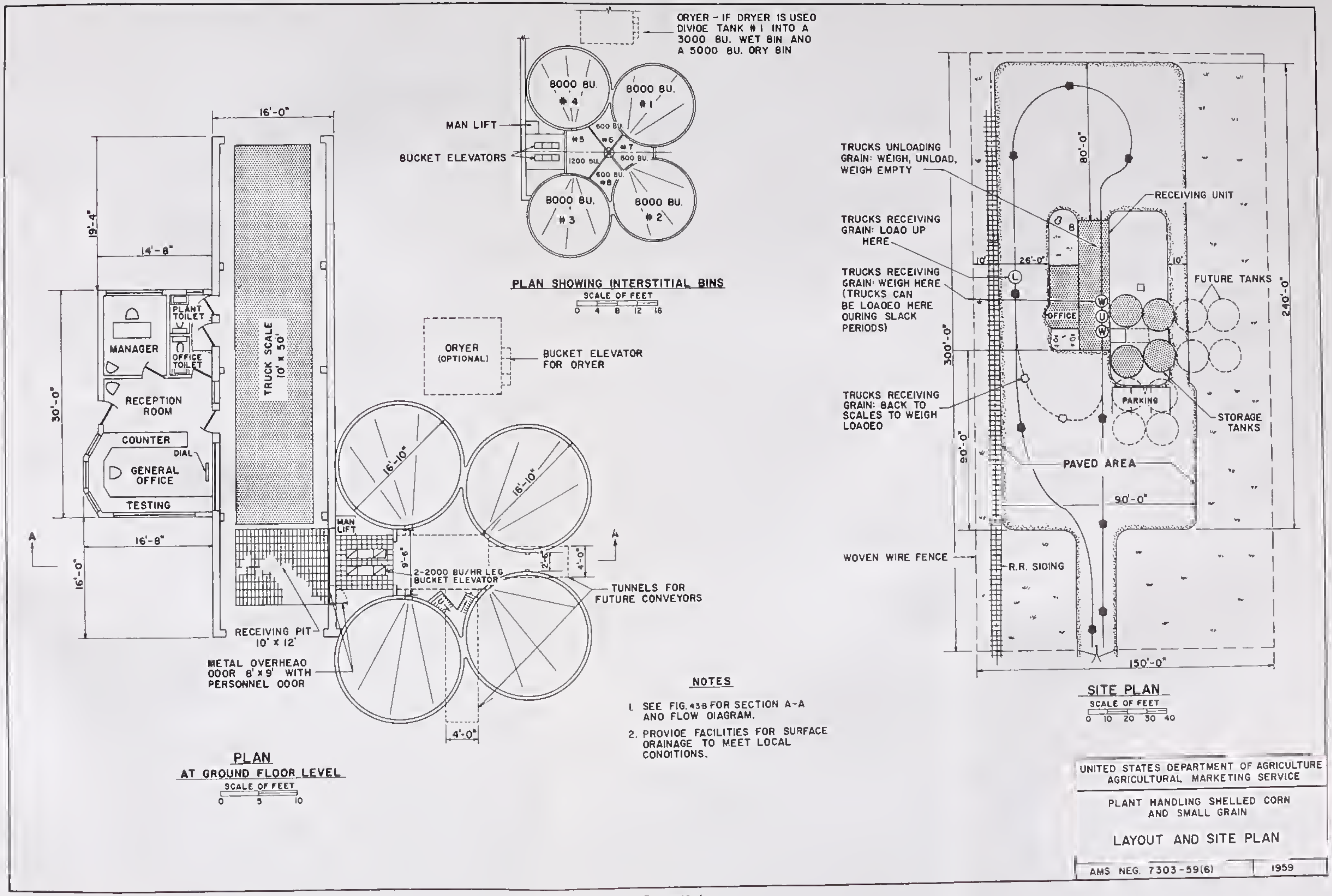

Figure 43 A.

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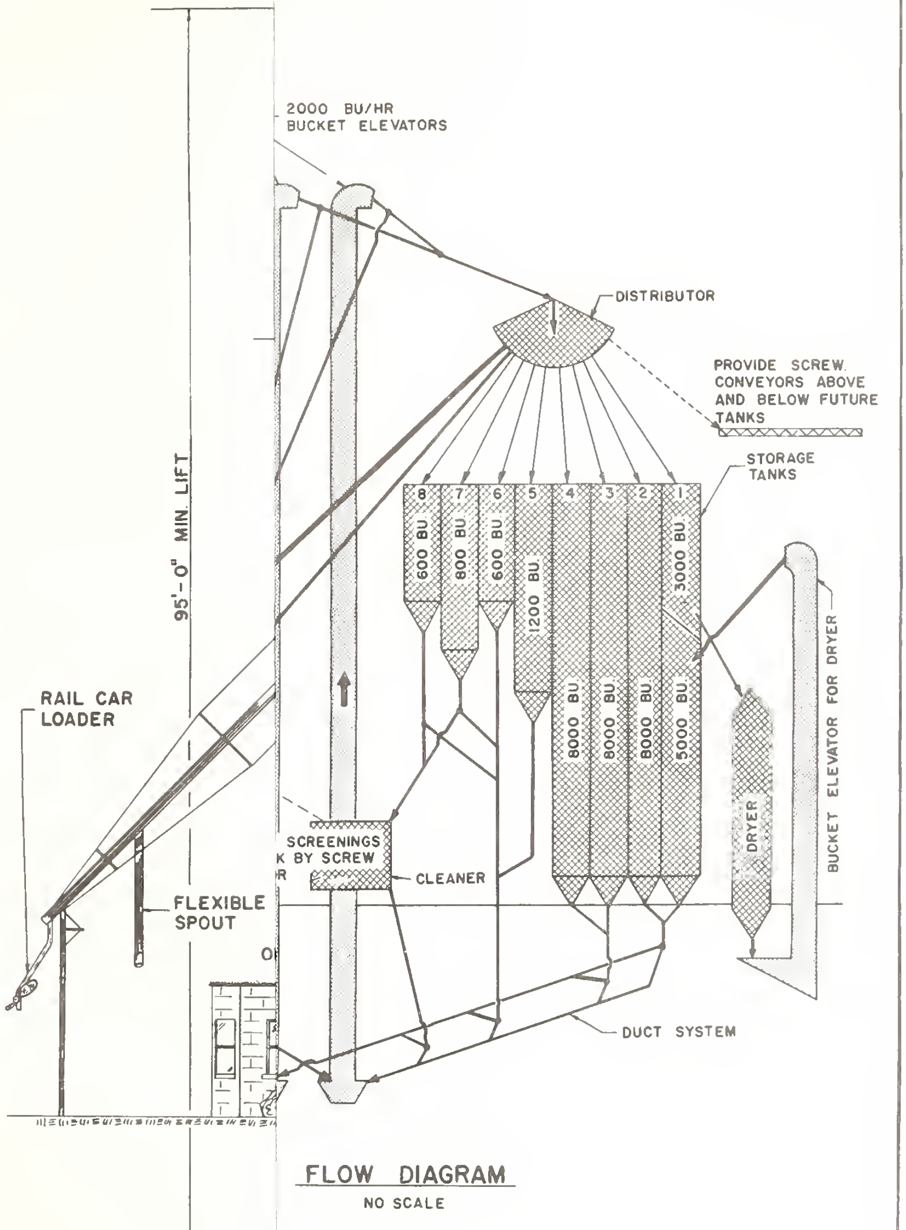

FLOW DIAGRAM

NO SCALE

UNITED STATES DEPARTMENT OF AGRICULTURE
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PLANT HANDLING SHELLED CORN
AND SMALL GRAIN

SECTION AND FLOW DIAGRAM

AMS NEG. 7304-59(6)	1959

542944 O - 60) Faces p. 40) No. 2

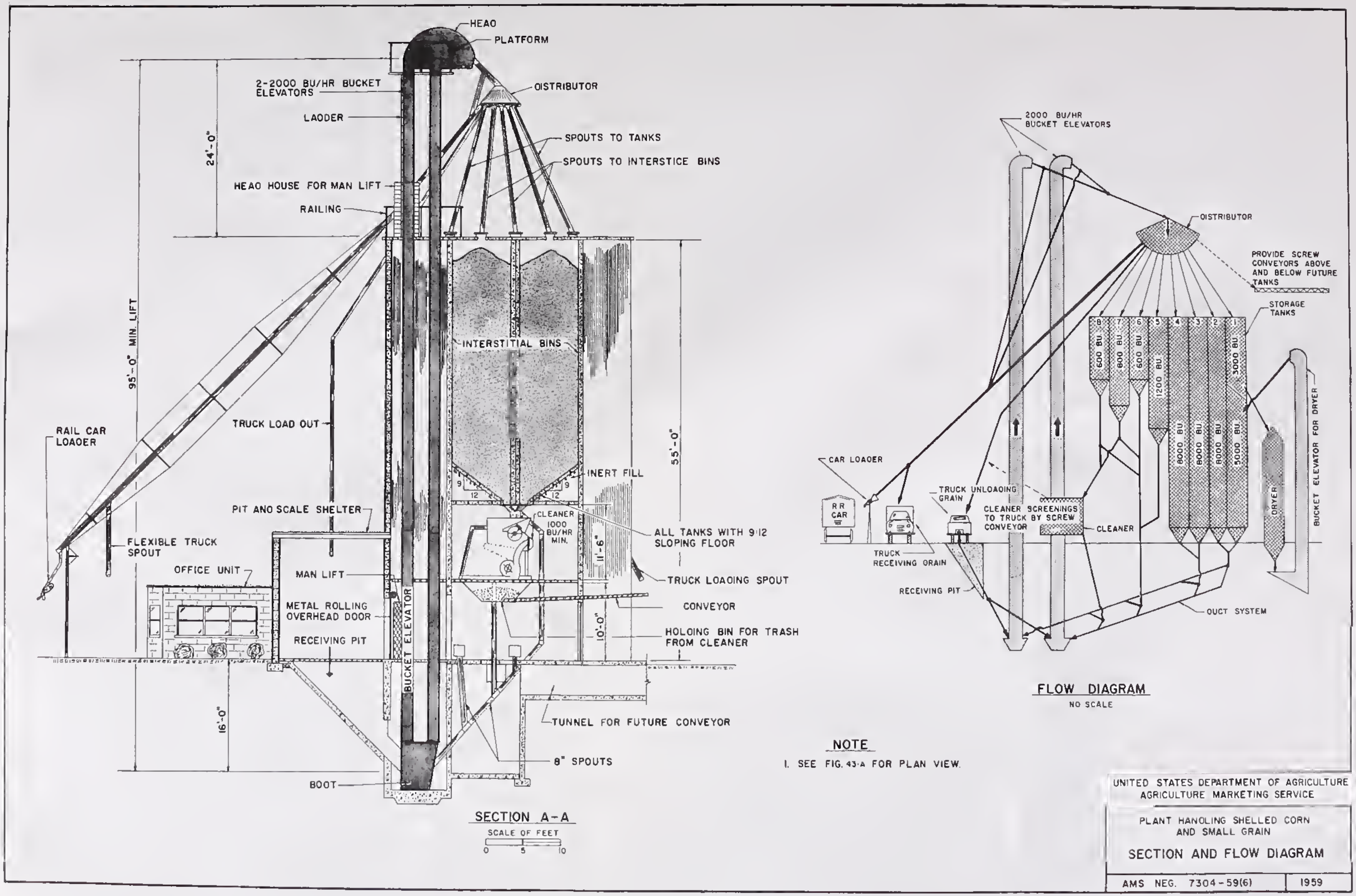


Figure 43 B.

542944 O - 60) Faces p. 40) No. 2

figure 43. It differs as follows: (1) The rail siding is located adjacent to the storage tanks, (2) the receiving pit is not as deep and is provided with a horizontal conveyor for moving grain to the leg, (3) a different office layout is shown, (4) the cleaner is located in a headhouse above the tanks, and (5) an automatic scale is provided for rail shipments. This arrangement would be suitable where ground water and soil conditions make deep excavation work costly; when much of the grain cleaning is to be done on receipt and the cleaned grain loaded directly into road trucks or rail cars; when the office unit is to be expanded and other units added rather than the storage unit expanded; and when grain may be received by rail.

This arrangement (fig. 44) has many of the advantages of the layout given in figure 43 with high speed rail car loading provided by gravity flow and no car loader required. However, the operator does not have a good view and control of loading-out operations from the office area. And, the headhouse above the tanks adds to the construction cost.

Buildings, Tanks, and Other Facilities

Reinforced, cast-in-place concrete tanks, with office and receiving units of concrete block construction were used in the layouts shown in figures 43 and 44. However, any of the materials previously discussed under the various units are adaptable to these layouts. For example, tanks and buildings of steel construction can be adapted to these layouts.

It is often advisable to put more into the cost of the building—deeper boots and receiving pits and sloping, self-cleaning tank bottoms and elevated tanks—to reduce the amount and cost of handling equipment. In selecting types of construction, consideration should be given not only to initial cost but also to annual costs such as; Maintenance, insurance and depreciation. As previously discussed, final selection will also depend upon local situations—site conditions, local contractors available, and local building codes. A perspective view of a plant based on the layout shown in figure 43 is shown on the cover.

Machinery and Equipment

The machinery and equipment required consists mainly of truck scales and lift, belt or screw conveyors when needed, elevator legs, distributor, spouting, grain cleaner, and possibly a grain dryer and automatic scale. Most of this machinery has been discussed under the various units. All handling equipment should be installed to provide for the smooth, continuous flow of grain. Bottlenecks should be eliminated when possible. All machinery and equipment should be fire safe and installed and maintained in accordance with the recommendation of the Mill Mutual Fire Prevention Board and other regulatory agencies.

The estimated initial construction costs for the plant shown in figure 43 is $96,000, table 3. See

TABLE 3.—*Estimated construction cost of a small country-point elevator handling shelled corn and small grain* [1]

Kind of work	Total units	Cost per unit	Total cost
Site preparation and outside work:		*Dollars*	*Dollars*
Clearing	1 acre	150. 00	150
Grading	5,000 sq. yd	. 10	500
Rail siding	270 feet	15. 00	4, 050
2-inch bituminous paving	2,200 sq. yd	1. 80	3, 960
6-inch gravel base	370 cu. yd	5. 00	1, 850
Woven wire fence	900 lin. ft	3. 50	3, 150
Drainage facilities	Lump sum		1, 000
Total			14, 660
Excavation and fill:			
Excavations for foundations, pits, etc	370 cu. yd	1. 50	555
Gravel fill for floor slabs	240 cu. yd	5. 00	1, 200
Total			1, 755
Concrete work:			
Tank walls	200 cu. yd	65. 00	13, 000
Tank roof slab	18 cu. yd	70. 00	1, 260
Tank foundations	80 cu. yd	35. 00	2, 800
Tank floor slabs	25 cu. yd	30. 00	750
Walls and floors for tunnels and pits	60 cu. yd	40. 00	2, 400
Floor slab, office and receiving	12 cu. yd	25. 00	300
Foundation, office and receiving	14 cu. yd	35. 00	490
Roof system, office and receiving	1,600 sq. ft	. 80	1, 280
Total			22, 280

See footnotes at end of table.

Table 3.—*Estimated construction cost of a small country-point elevtor handling shelled corn and small grain*—Continued

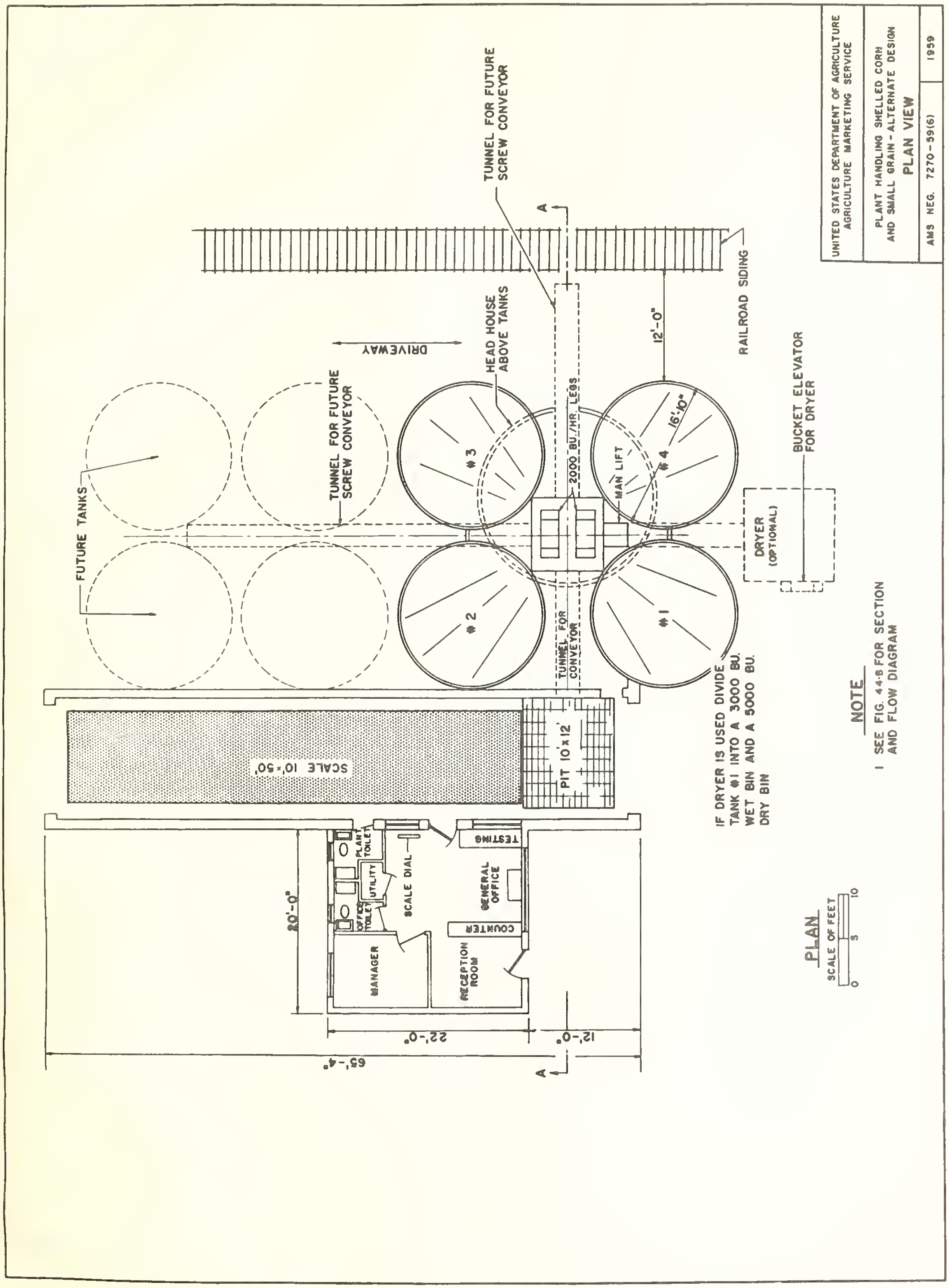
Kind of work	Total units	Cost per unit	Total cost
		Dollars	*Dollars*
Masonry:			
12-inch concrete block	3,000 sq. ft	. 70	2, 100
8-inch concrete block	450 sq. ft	. 60	270
4-inch concrete block	250 sq. ft	. 50	125
4-inch glazed concrete block	150 sq. ft	1. 10	165
Lentils and sills	100 lin. ft	1. 00	100
Total			2, 760
Steel work:			
Girders for hoist track	2,000 lbs	. 15	300
Framing for floors and pit	1,000 lbs	. 17	170
Lightweight grating	200 sq. ft	3. 00	600
Heavy grating	120 sq. ft	4. 00	480
Guard rails	100 lin. ft	3. 00	300
Platform, catwalks, ladder, miscellaneous	Lump sum		600
Total			2, 450
Miscellaneous items:			
4-ply T and G roofing	2,500 sq. ft	. 18	450
Asphalt tile flooring	450 sq. ft	. 35	158
Windows	Lump sum		500
Doors	Lump sum		2, 200
Heating and ventilation	Lump sum		900
Lighting	Lump sum		600
Plumbing	Lump sum		650
Miscellaneous flashing, insulation, etc	Lump sum		800
Total			6, 258
Equipment: [2]			
Legs, 94′, 2,000 bu./hr	2	4, 400. 00	8, 800
Distributor	1	430. 00	430
8-inch spouting	360 feet	4. 00	1, 440
Gates, etc	Lump sum		800
4-inch screw conveyor	1	225. 00	225
Man lift, 56-feet	1	1, 300. 00	1, 300
Truck lift, 5-ton	1	1, 400. 00	1, 400
Wiring and controls	Lump sum		1, 500
Cleaner, 1,000 bu./hr	1	2, 700. 00	2, 700
Truck scales, 50-ton	1	6, 000. 00	6, 000
Car loader	1	1, 250. 00	1, 250
Miscellaneous	Lump sum		1, 000
Total			26, 845
Grand total			77, 008
Plus 25% overhead and profit			19, 252
Grand total for the plant	Rounded to		96, 260 96, 000

[1] Dryer and other accessories such as office furniture, testing equipment and other similar items are not included in this cost estimate.

[2] Unit prices include cost of necessary drives and motors.

page 3 for a discussion of the assumptions used and the significance of the cost data presented here. The cost of $96,000 for a plant holding only 32,000 bushels of grain is high—$3 per bushel when considered on a per-bushel basis. However, this plant is intended to be a merchandising and handling facility rather than a storage facility. It is assumed that a plant of this type would handle about 320,000 bushels per year. The main revenue from operating this type of plant would come from handling, merchandising, cleaning, and drying grain, and not so much from storing grain.

The estimated annual facility costs—depreciation, interest, insurance, taxes, and maintenance are given in table 4.



UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURE MARKETING SERVICE
PLANT HANDLING SHELLED CORN
AND SMALL GRAIN - ALTERNATE DESIGN
PLAN VIEW
AMS NEG. 7270-59(6)
1959
TUNNEL FOR FUTURE
SCREW CONVEYOR
A
RAILROAD SIDING
12'-0"
DRIVEWAY
HEAD HOUSE
ABOVE TANKS
FUTURE TANKS
TUNNEL FOR FUTURE
SCREW CONVEYOR
#3
#2
#4
#1
2000 BU./HR. LEGS
MAN LIFT
16'-10"
BUCKET ELEVATOR
FOR DRYER
DRYER
(OPTIONAL)
TUNNEL FOR
CONVEYOR
SCALE 10'×50'
PIT 10'x12'
IF DRYER IS USED DIVIDE
TANK #1 INTO A 3000 BU.
WET BIN AND A 5000 BU.
DRY BIN
NOTE
1 SEE FIG. 44-B FOR SECTION
AND FLOW DIAGRAM
TESTING
PLANT TOILET
UTILITY
OFFICE TOILET
SCALE DIAL
GENERAL OFFICE
COUNTER
MANAGER
RECEPTION ROOM
20'-0"
22'-0"
12'-0"
65'-4"
PLAN
SCALE OF FEET
0
5
10

Figure 44 A.

Table 4.—*Estimated annual facility cost for a grain elevator handling shelled corn and small grains* [1]

Item	Assumed rate	Annual cost
	Percent	*Dollars*
Depreciation: [2]		
Buildings	2.5	1,500
Equipment	5.0	1,800
Interest	[3] 6.0	2,880
Maintenance and repairs:		
Building	.75	450
Equipment	1.5	540
Taxes	1.0	960
Insurance	.30	288
Total annual facility cost		8,418

[1] Based on a construction cost of $96,000 (buildings $60,000 and equipment including plumbing, heating, and electrical, $36,000). See pages 3 and 4 for basis and assumptions used for cost estimates.
[2] Depreciation as used here is based mainly on physical factors such as type and quality of construction; for accounting purposes, in making construction loans, and in business planning a shorter useful life than shown above is often used.
[3] Based on the average value of the facility.

Development of a Plant for Handling Ear Corn, Shelled Corn, and Small Grain

The various units previously discussed—receiving, office, storage, and corn shelling—were coordinated and modified to form a complete plant. The plant is somewhat similar to the one developed for handling shelled corn and small grains. See section on development of a plant, page 38.

Shortcomings in Existing Plants

In developing designs for this type of plant efforts were made to avoid the faults and inefficiencies found in existing plants handling ear corn, shelled corn and small grains. Many plants had the shelling unit remote from the storage unit and away from the main plant requiring continuous supervision at both locations during the peak season. The shelled corn had to be moved by truck from the shelling unit to the storage unit requiring additional labor and equipment.

Generally, the dump pit for receiving ear corn was too small and required considerable hand shoveling around the pit after each load. Most were open pits covered by heavy steel, hinged, counterweighted doors that had to be closed before a loaded vehicle could pass over it. Many of these doors were subjected to rough use and were in poor condition. Some of the plants had only haphazard facilities for handling and burning cobs and shucks.

Recommendations and Improved Designs

Layout and Arrangement

The layouts are similar to those shown for receiving only shelled corn and small grains. Section "Development of a Plant for Handling Shelled Corn and Small Grain," page 38.

It is suggested that the scales and office unit be located away from the storage and shelling units to eliminate the noise and dust problem around the office. The four circular tanks were grouped together as in figure 45, with the cleaner located under the interstitial bins.

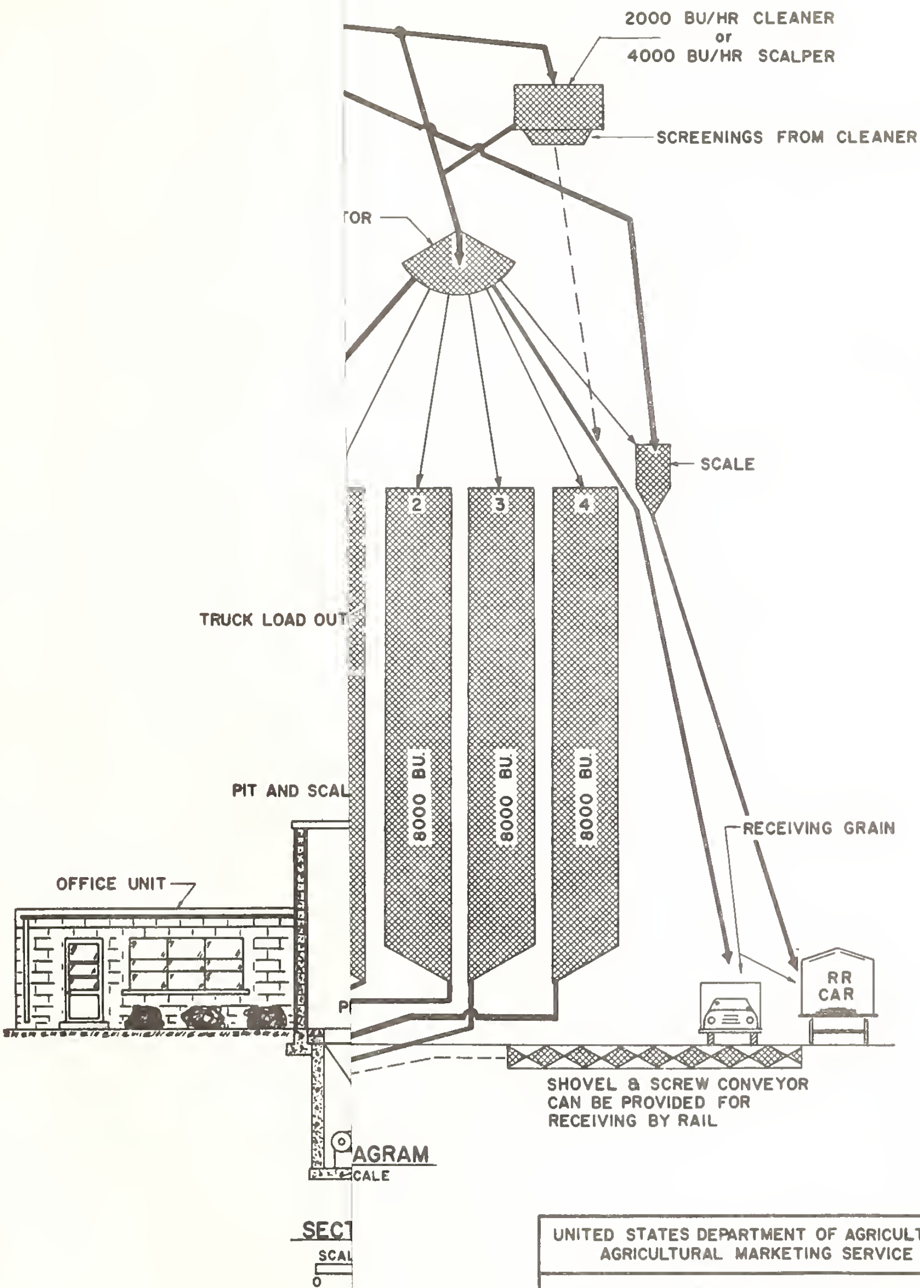
The receiving unit was modified to include the shelling unit and a second dump pit for ear corn (fig. 45). The two pits should be separated by at least 3 feet to prevent grain spilling over from one pit into the other. Grain flows by gravity from the small grain pit into the main elevator legs. The ear corn moves from the ear corn pit to the sheller through a 16-inch diameter screw conveyor. The shelled corn moves by horizontal conveyor from the sheller to the main elevator legs after which the flow is the same as that in the flow diagram, figure 43b. The same truck lift is used to unload vehicles at both dump pits.

The ear corn pit can be located at the side of the small grain pit rather than behind it as shown. However, this arrangement requires duplication of unloading equipment and probably a 2-man crew for most efficient unloading.

The office unit and scales (fig. 45) are located some distance from the main plant with the scales in line with the receiving unit. The rail siding is located on the office side but could be located on the other side. The site arrangement includes area for truck traffic and parking area and also area for future expansion (fig. 45).

The arrangement shown in figure 45 provides for: (1) Complete gravity flow except for the corn shelling operations; (2) a minimum of handling equipment; (3) a bay window in the office to facilitate observation of plant operations from the general office area; (4) space for adding storage tanks in two directions for future expansion; (5) two legs for flexibility of operations (loading and unloading simultaneously, and receiving small grain and shelling corn simultaneously); (6) the cleaner in a location convenient for inspection and maintenance; (7) all grain and corn receiving operations in one central location, thus minimizing the elevating equipment requirements; and (8) the office unit and weighing operations to be away from dirt and dust resulting from the corn shelling operations.

The disadvantages of this layout are somewhat the same as those given on page 40. The plant does not lend itself too well to a one-man operation. An intercommunication system between the office and the receiving unit is desirable.



UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

PLANT HANDLING SHELLED CORN
AND SMALL GRAIN - ALTERNATE DESIGN

SECTION AND FLOW DIAGRAM

AMS NEG. 7269-59(6)	1959

542944 O - 60 (Faces p. 44) No. 1

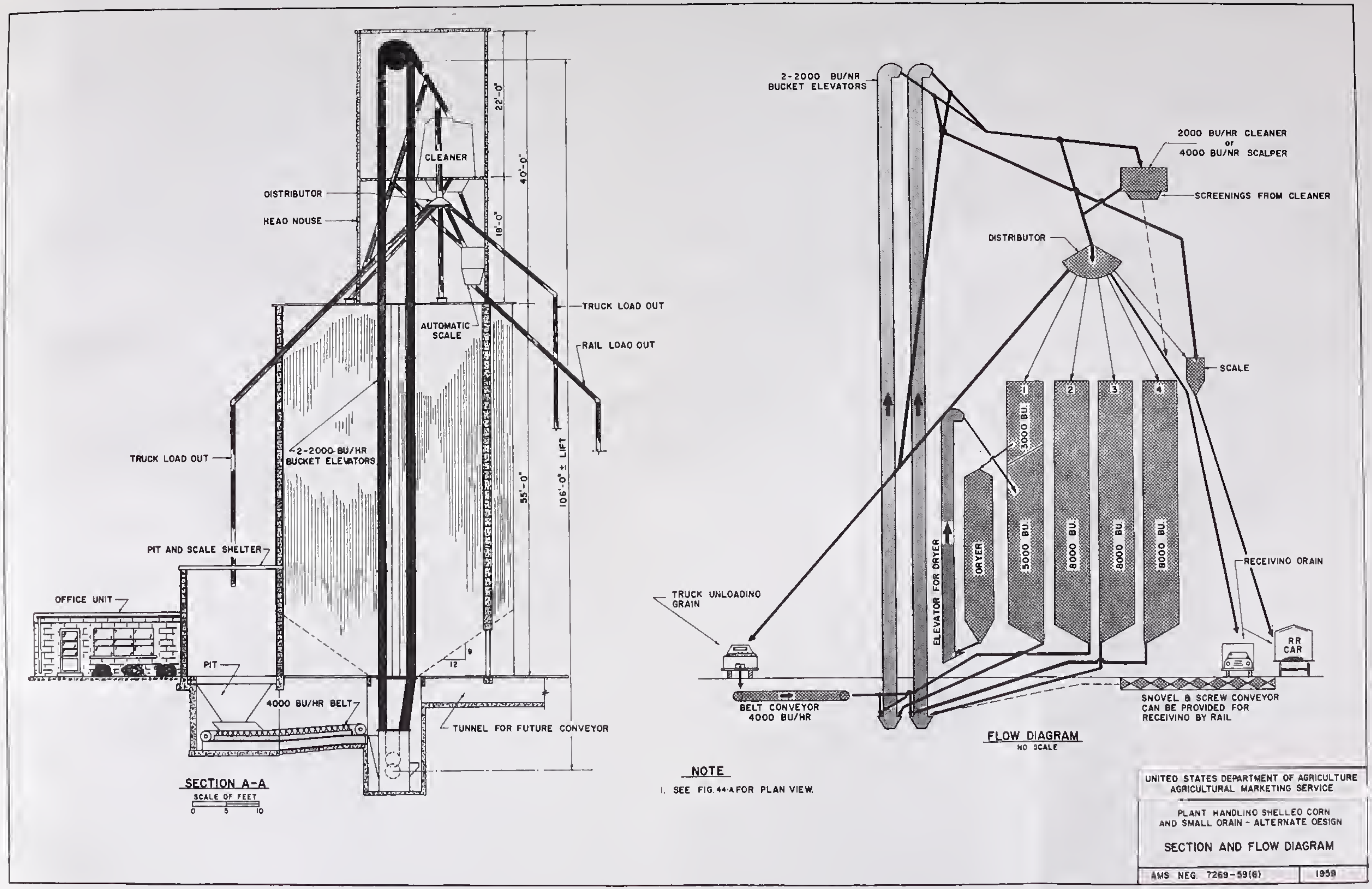
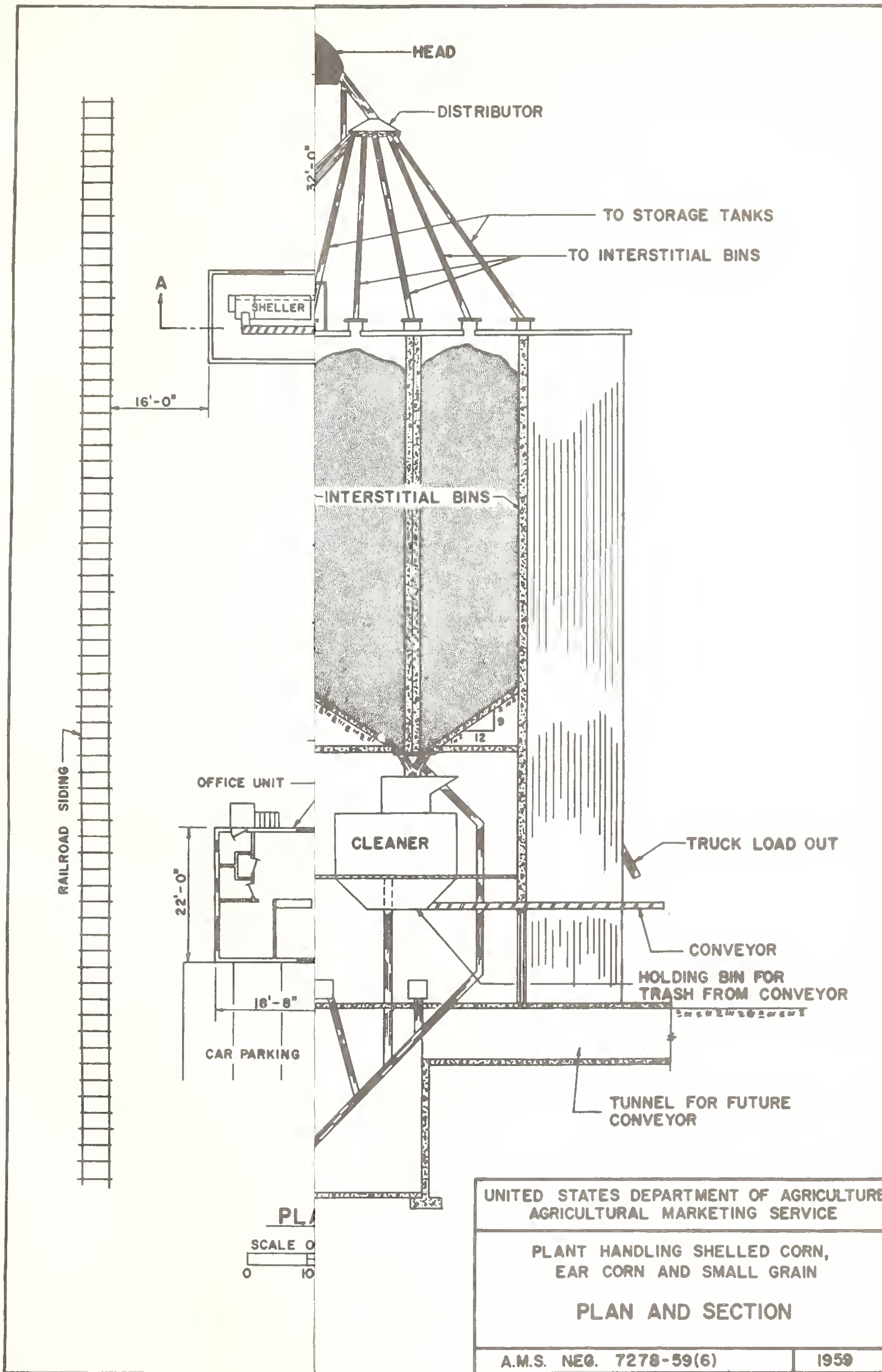


Figure 44 B.

542944 O - 60 (Faces p. 44) No. 1



542944 O - 60 (Faces p. 44) No. 2

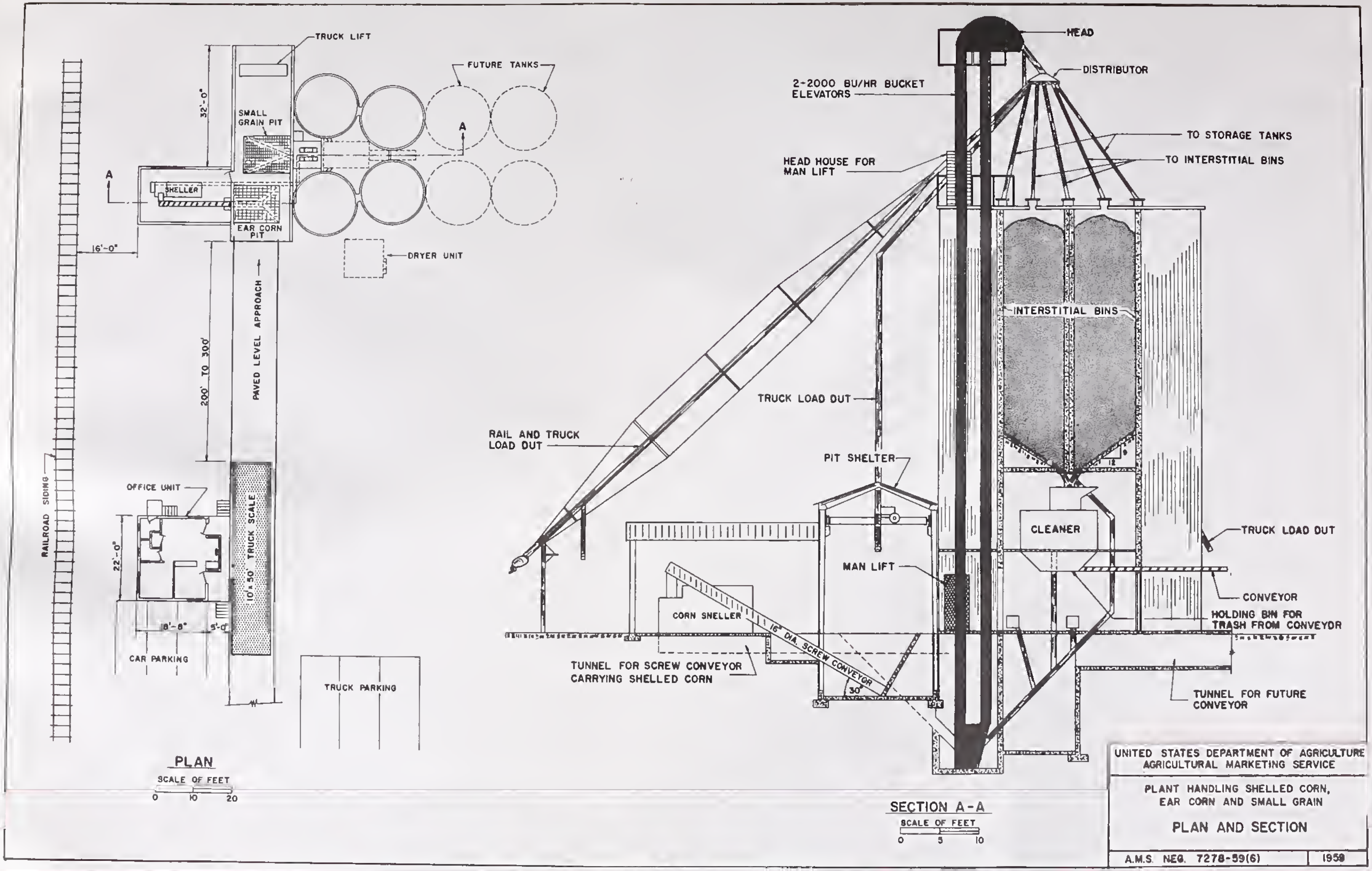


Figure 45.

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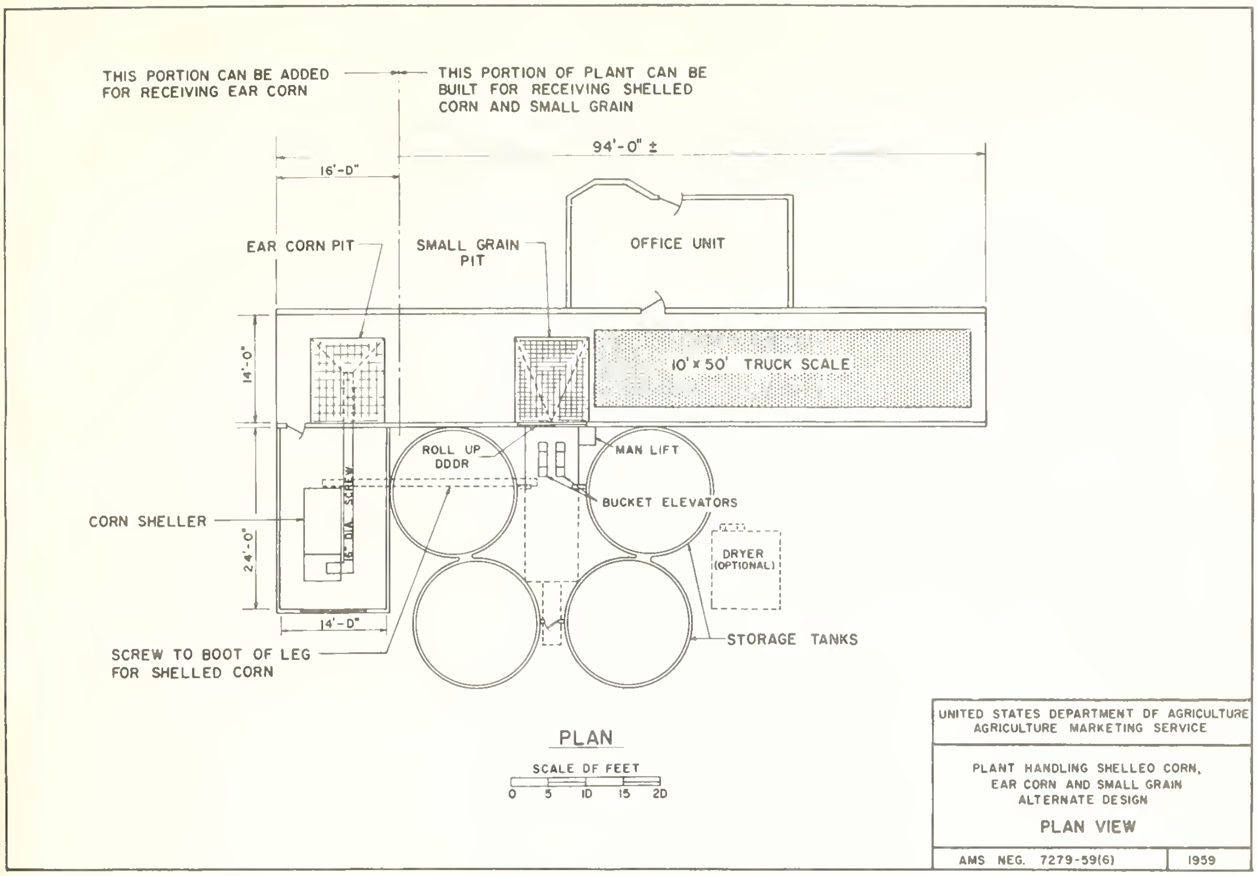

Figure 46.

Alternate Arrangement

Figure 46 shows an alternate arrangement similar to that shown in figure 43, but with a shelling unit added, with all units combined, thus all observations and supervision are within the plant. The scale and both dump pits are in the same receiving unit to minimize the amount of handling equipment needed. The same truck lift is used for both dump pits and a horizontal conveyor moves the shelled corn from the sheller into the main elevator leg. The office unit may be moved (fig. 46) further away from the noise and dust of the shelling unit.

Development of a Plant for Receiving Mainly Ear Corn

The various units—receiving, office, shelling, and storage—were combined and modified as necessary to form a complete plant for receiving and shelling ear corn and storing the shelled corn. This type of plant is rather common in the Southeast; however, with the increasing use of field picker-shellers, undoubtedly the demand will be less in the future. Where an operator anticipates future receipts of shelled corn and small grains he should consider the suggested layouts for the plant for handling ear corn, shelled corn and small grains, pages 43 and 44. Often the shelling unit with a truck lift and receiving pit is grouped together but separate from the main elevator. The shelled corn is then moved from the sheller to the main storage tanks by truck or by a long conveyor.

Many of the existing plants studied had many of the shortcomings previously discussed on pages 39 and 44.

Recommendations and Improved Layouts

Figure 47 shows a suggested arrangement or layout of a plant similar to the one for handling shelled corn and small grain, page 38. The 4 storage tanks are grouped near the shelling unit and the office unit is adjacent to the receiving unit (fig. 47). Particular attention should be given to the insulation of the wall or partition separating the office and the receiving unit, to stop noise and the dust of shelling operations. See section on advantages and disadvantages of combining truck scales with the receiving unit, page 23.

The capacity of the bucket elevator can be lower

for this plant than for those receiving shelled corn and small grain. Its capacity should be coordinated with that of the sheller; generally, a capacity of 1,000 bushels per hour would be satisfactory. If it is anticipated that the plant may be converted to receive shelled corn and small grain, provision should be made for the addition of a higher capacity bucket elevator.

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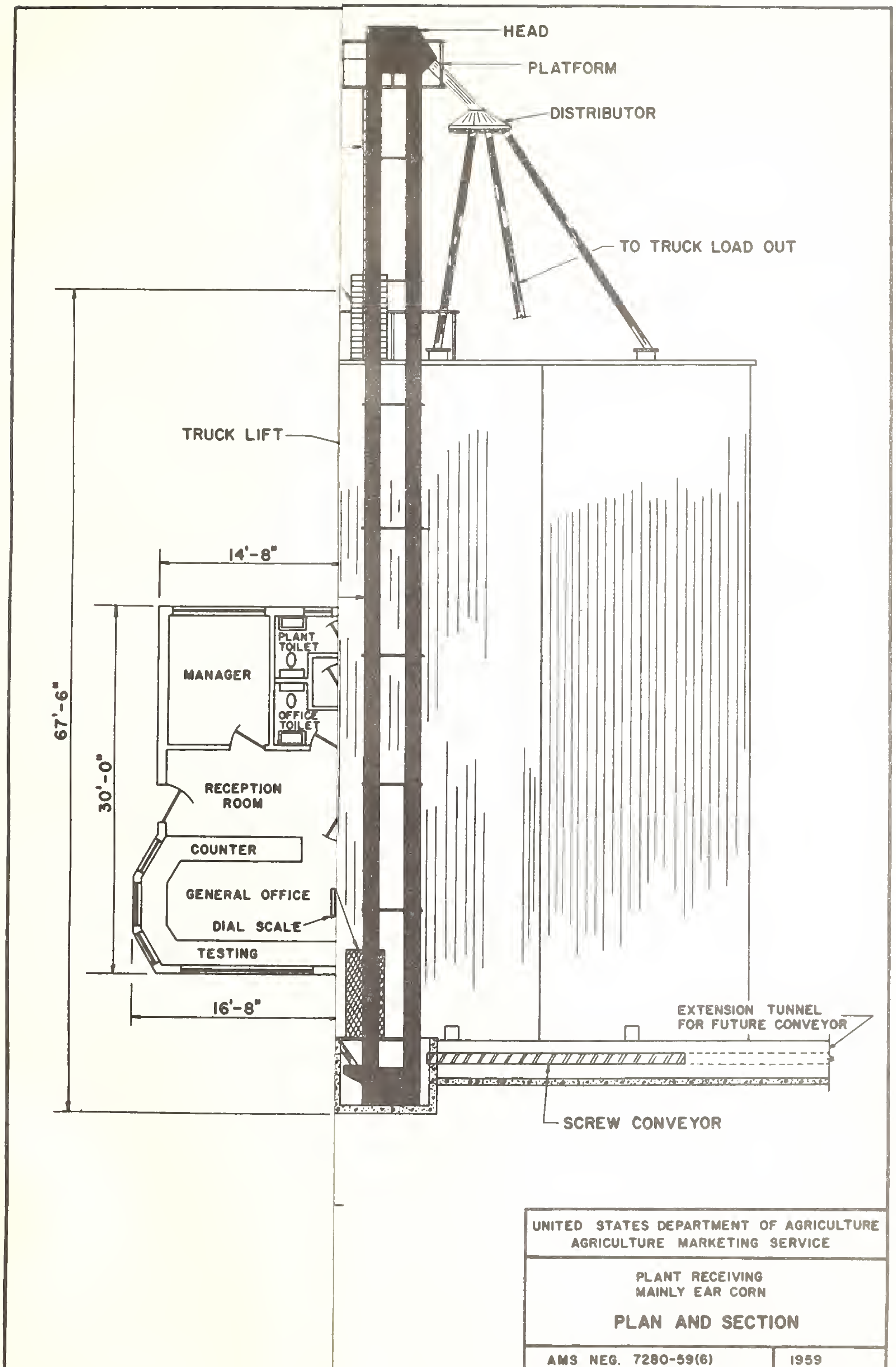

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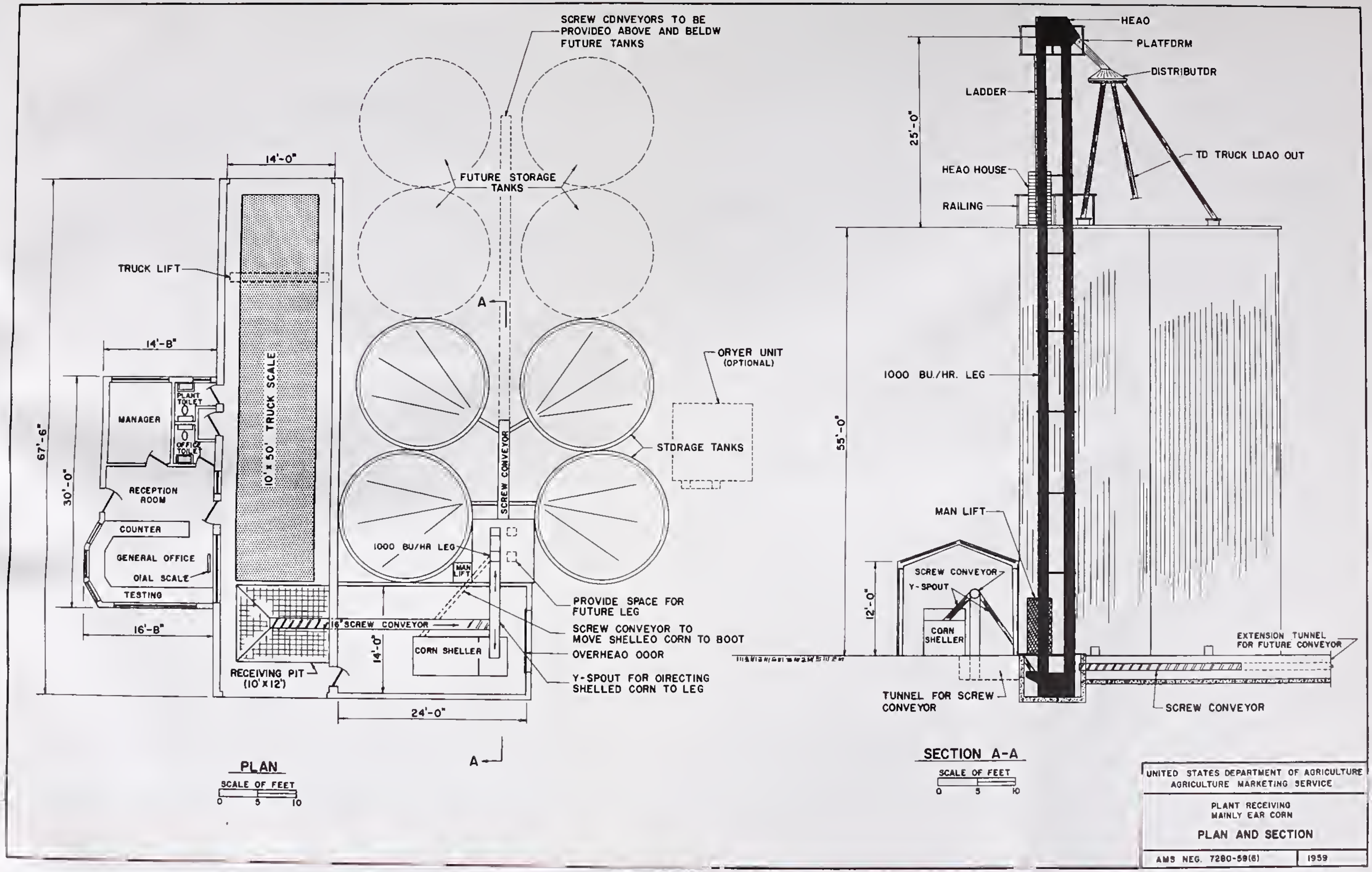

SCREW CONVEYORS TO BE PROVIDED ABOVE AND BELOW FUTURE TANKS
FUTURE STORAGE TANKS
14'-0"
TRUCK LIFT
14'-8"
MANAGER
PLANT TOILET
OFFICE TOILET
RECEPTION ROOM
COUNTER
GENERAL OFFICE
DIAL SCALE
TESTING
67'-6"
30'-0"
16'-8"
10' x 50' TRUCK SCALE
A
DRYER UNIT (OPTIONAL)
STORAGE TANKS
SCREW CONVEYOR
1000 BU/HR LEG
MAN LIFT
16" SCREW CONVEYOR
14'-0"
CORN SHELLER
RECEIVING PIT (10' x 12')
24'-0"
PROVIDE SPACE FOR FUTURE LEG
SCREW CONVEYOR TO MOVE SHELLED CORN TO BOOT
OVERHEAD DOOR
Y-SPOUT FOR DIRECTING SHELLED CORN TO LEG
PLAN
SCALE OF FEET
0 5 10
HEAD
PLATFORM
DISTRIBUTOR
LADDER
25'-0"
TO TRUCK LOAD OUT
HEAD HOUSE
RAILING
1000 BU./HR. LEG
55'-0"
MAN LIFT
SCREW CONVEYOR
Y-SPOUT
12'-0"
CORN SHELLER
EXTENSION TUNNEL FOR FUTURE CONVEYOR
TUNNEL FOR SCREW CONVEYOR
SCREW CONVEYOR
SECTION A-A
SCALE OF FEET
0 5 10
UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURE MARKETING SERVICE
PLANT RECEIVING
MAINLY EAR CORN
PLAN AND SECTION
AMS NEG. 7280-59(6)
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Figure 47.

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Appendix A

Summary of Field Studies

Seven plants were studied in Georgia. Six of these were steel storage tanks; one was welded steel, the other five were bolted steel. The seventh plant was of heavy, wood construction. All the plants except one had corn shellers and in each case the sheller was the limiting factor for the volume of corn that could be handled. Only one plant had a grain dryer. Two plants had storage for ear corn and bought both shelled and ear corn. All of these Georgia plants had the scales and office facilities remote from the storage and dump pit.

Six plants were studied in North Carolina; three with bolted steel tanks; one with a combination of bolted steel tanks and cast-in-place concrete; one small complete cast-in-place concrete structure; and the sixth built with hollow clay blocks. The six plants ranged in capacity from 20,000 to 74,000 bushels. As field picker-shellers are popular in this area, there was a large amount of shelled corn received at the elevators. Only two plants had stationary shellers. Three other plants had portable farm-type shellers that are used at the farm, thus eliminating the problem of disposing of the cobs and shucks at the elevator site.

Four of the six plants each had a grain dryer and a cleaner and two had two dryers each. The handling equipment had considerably larger capacities in the North Carolina plants than in the Georgia plants. At peak periods of receipts, grain is elevated directly into large trucks for terminal market shipment. All small country elevators studied had high daily handling capacities with some handling as much as 25,000 bushels per 16-hour day. All plants had the scales and office located remote from the storage facility and the unloading area.

One of the plants in North Carolina handled about 200,000 bushels of corn per year. In addition to buying and selling corn, this plant manufactured edible corn products such as corn meal and grits as well as livestock feeds. The other five plants handled from 600,000 to 1,000,000 bushels of grain per year.

Seven plants were studied in Mississippi, most of them in the Delta area. Four of the plants had steel tanks; two concrete stave tanks and the seventh cast-in-place concrete tanks. The activities in these Mississippi plants were somewhat different from those of the plants studied in Georgia and North Carolina. More different kinds of grain were handled and the handling equipment capacities were more varied. The storage capacity of the seven plants ranged from 15,000 to 60,000 bushels.

Four of the seven plants had corn shellers and the operators were mainly interested in the handling of corn. Three plants had shellers with a rated capacity of 1,200 bushels per hour and the other plant with 800 bushels per hour. Only three of the plants had dryers and one of these had never been used. In one plant the dryer was used extensively to dry grain sorghum. Six of the plants had cleaners. Four of the plants visited had the scales and office located remote from the storage facility. The other three plants had the scales and dump pit in the drive-through driveway with the office facilities adjacent to the driveway.

The tables which follow summarize some of the important information obtained from the field studies.

TABLE 5.—*Summary of field studies on existing elevator storages in Georgia, North Carolina, and Mississippi*

States	Plants studied	Major business operation		Number of turn-overs [1]	Number of different grains handled	Periods of peak receipts	Plants shipping by rail
		Buying and selling grain	Milling or feed mixing				
	Number	*Number*	*Number*	*Average*	*Average*	*Dates*	*Number*
Georgia	6	4	2	17.25	2.8	9/1 – 1/1 5/15– 7/15	1
North Carolina	6	4	2	25.07	2.0	9/15–12/15	3
Mississippi	7	5	2	6.04	3.1	9/1 – 2/1 6/1 – 7/15	5
Total	19	13	6	----------	----------	------------	9

[1] Turnover is amount of grain received annually at the plant divided by the plant's storage capacity.

TABLE 6.—*Types and percentage of grains received: Percent of total yearly receipts* [1]

Location of plants	Ear corn	Shelled corn	Oats	Wheat	Soy-beans	Other
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Georgia	88	------	6	3	-- ---	3
North Carolina	18	66	------	------	16	------
Mississippi	41	6	15	14	16	[2] 8

[1] Averaged from 19 plants studied; 6 plants in both Georgia and North Carolina and 7 plants in Mississippi.
[2] The major portion of this was grain sorghum.

Appendix B

Grain Pressures and the Structural Design of Grain Storage Tanks

The major structural loads on storage tanks are those resulting from pressure of the stored grain on the bin walls. Values for grain pressures and loads and methods of designing tanks are not fully agreed upon by authorities. Because adequate basic research on grain pressures is lacking, it is not proposed here to make specific recommendations or to provide standards for the grain pressures and loads; however, certain principles and precautions are given relative to the structural design of grain storage tanks or bins. Although there is some disagreement among the works listed in the Bibliography, the engineer designing grain storages should review those pertaining to the structural design of grain tanks. And, with the information available and sound engineering judgment he should be able to design a safe yet economical grain storage structure.

The grain pressures and loads in this report are based, in general, upon the well-known theories of H. A. Janssen. Figure 48 shows the static lateral grain pressures for grain tanks at various diameters as computed from Janssen's formulas and figure 49 gives the vertical loads. The pressures and loads determined from Janssen's formula may be used as a basis for tank designs, but certain modifications should be made and cautions taken as listed in the next paragraph. Janssen's equations are as follows:

Let:

e = the base of the naperian system of logarithms

u' = the coefficient of friction of grain on the bin wall. (Usually between 0.3 and 0.5) (14).

w = weight of grain in pounds per cubic foot. (50 lbs/cu. ft. used for this report; for densities of various grains, see reference (14)).

y = depth below grain surface in feet.

k = ratio in lateral pressure to vertical pressure, (0.3 to 0.6 is often used, but see reference (9)).

R = hydraulic radius of bin (horizontal cross-sectional area of the bin divided by the circumference of the bin).

V = unit vertical pressure of the grain in pounds per square foot.

L = unit lateral pressure of grain in pounds per square foot.

P = total lateral pressure for a unit width of wall, pounds per foot.

$P.u'$ = total vertical grain load carried by one unit width of wall.

at a point y

$$V=\frac{wR}{ku'}(1-e^{-ku'y/R})$$

$$L=kV$$

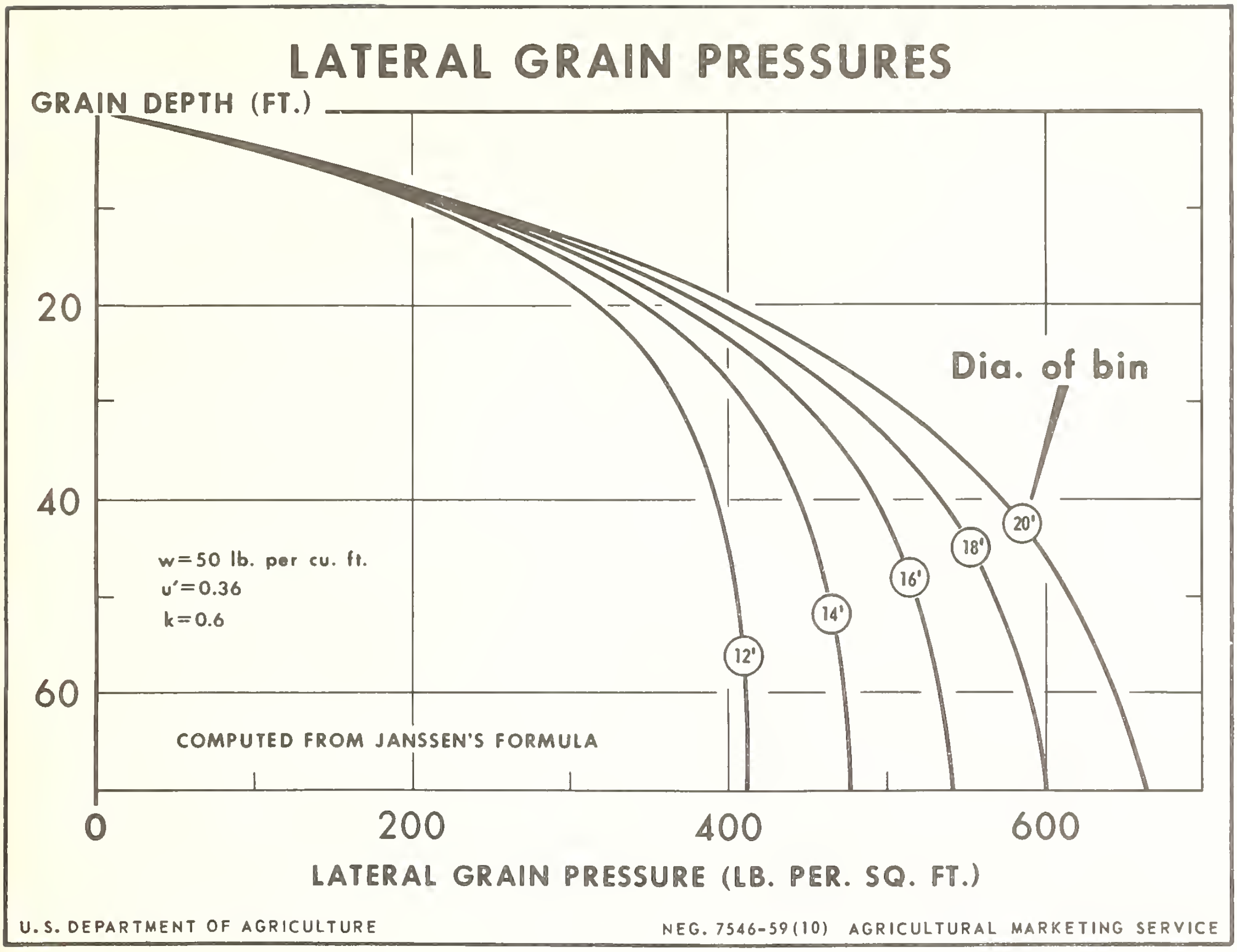

Figure 48.

for a unit width of wall to depth of y

$$P=\int_o^y Ldy=\frac{wR}{u'}\left[y-\frac{R}{ku'}\,(1-e^{-ku'y/R})\right]$$

$$P.u'=wR\left[y-\frac{R}{ku'}\,(1-e^{-ku'y/R})\right]$$

$$=wR\left[y-\frac{R}{ku'}\right]\text{ (approx.)}$$

In using Janssen's formulas in designing grain storage tanks several precautions should be taken. Consider the selection of k (the ratio of lateral to vertical pressure. Although most designers use a value somewhere between 0.3 and 0.6 for grain storages, according to some theoretical analysis it could vary between 0.3 and 3.0, or could change with the depth of the grain (*9*). Some designers select a large value for u' for vertical grain loads and a small value for lateral grain pressures, thereby designing the tank for greater grain loads.

Another important question is the amount by which to increase these static pressures and loads for possible increases in stresses during loading and unloading of the tanks. There has been considerable disagreement between authorities on this point (*4*, *6*, *7*, *12*). Unloading the grain from the sides of the tank is especially a problem. Many designers increase the static loads by 25 to 50 percent to take care of increased loads from side unloading (*3*).

When tanks are grouped together with interstitial bins the walls of the tanks must withstand the bending moments resulting when an interstitial bin is loaded and the surrounding tanks are empty. It is often advisable to thicken the walls at the corner of intersecting bins (*13*, *16*).

In special cases, tanks must be designed to withstand increased grain pressures resulting from increases in the moisture content of the grain while in storage (*5*) and pressures from internal air pressures. Concrete tanks must be designed to resist temperature and shrinkage cracks (*11*) and steel tanks to resist localized buckling. And, as

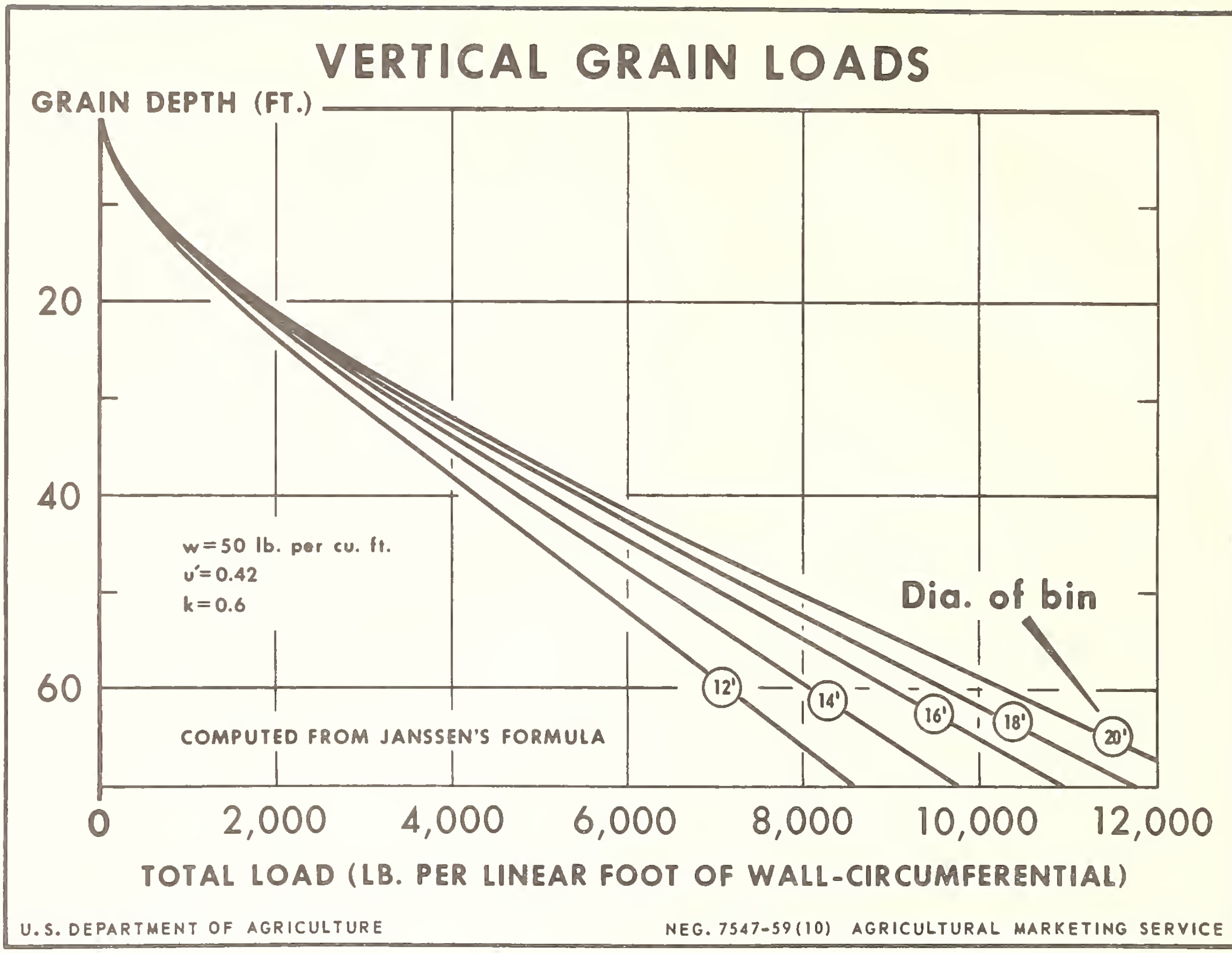

Figure 49.

shown in figure 50, lateral loads and other overturning forces must be considered.

Appendix C

Selection of Tank Dimensions

In selecting the dimension of a tank it is desirable to obtain the most storage volume for the least amount of wall, floor, and roof material needed in the construction of the tank. For example, assume a cylindrical tank with a 45° hopper bottom (45° used to simplify computations) with the same thickness and type of material used throughout. The greatest storage volume for the least material would theoretically be obtained when the height equals 1.4 times the radius ($h=1.4\ r$), (fig. 51). However, in actual practice for tanks of this type, the hopper bottom and possibly the roof area would cost more than the wall. For example, assume that the hopper area with its support or foundation costs 4 times as much per square foot as the wall area, and that the roof area with trusses or other framing costs 1.5 times as much per square foot as the wall area; also, assume that the wall material is the same throughout. Then the lowest construction costs would theoretically be when the height equals 6.2 times the radius ($h=6.2\ r$), (fig. 51). This ratio of height to radius is somewhat theoretical and in practice, the most economically shaped tank would depend upon materials used, construction methods, soil conditions, and other factors.

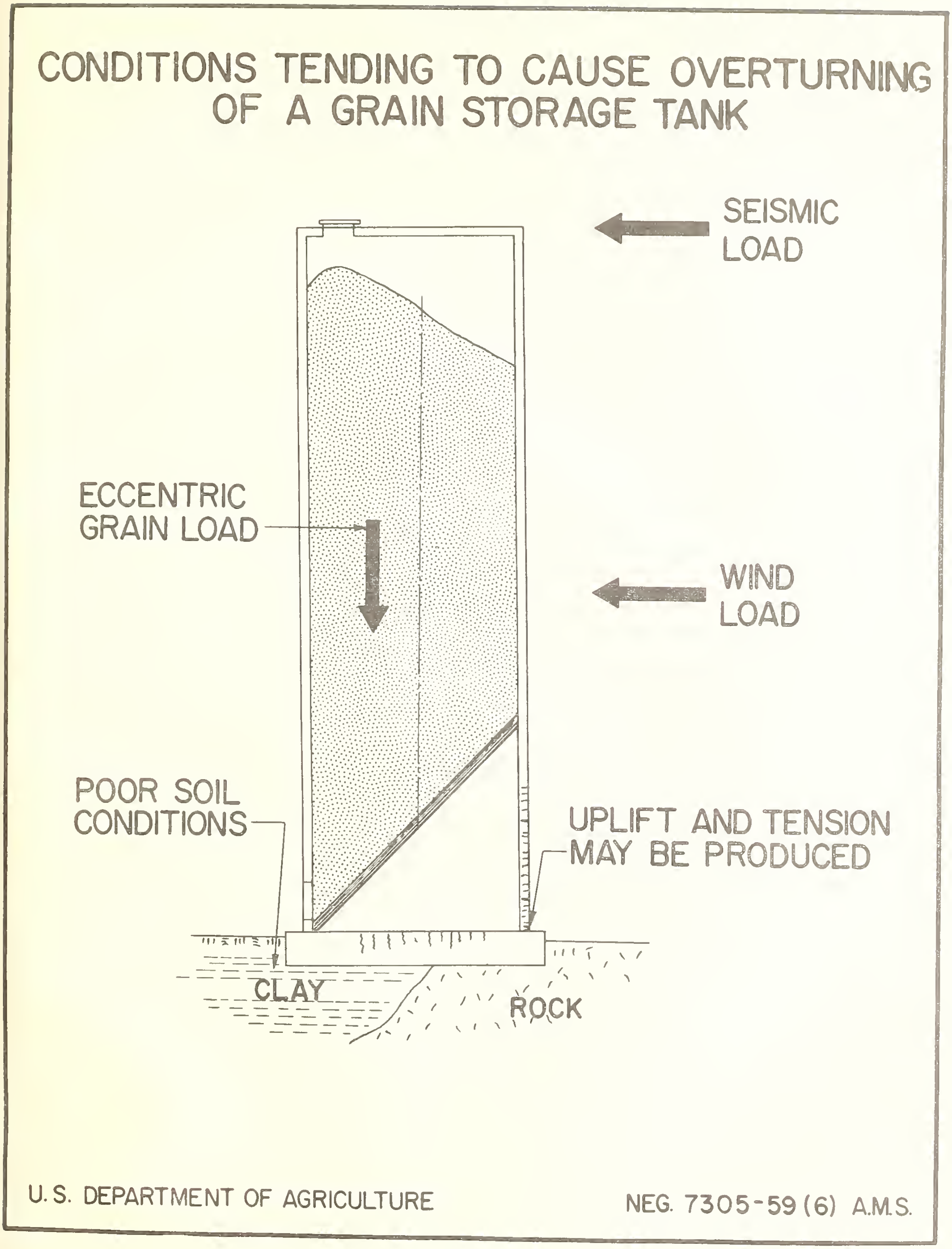
CONDITIONS TENDING TO CAUSE OVERTURNING OF A GRAIN STORAGE TANK
SEISMIC LOAD
ECCENTRIC GRAIN LOAD
WIND LOAD
POOR SOIL CONDITIONS
UPLIFT AND TENSION MAY BE PRODUCED
CLAY
ROCK
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Figure 50.

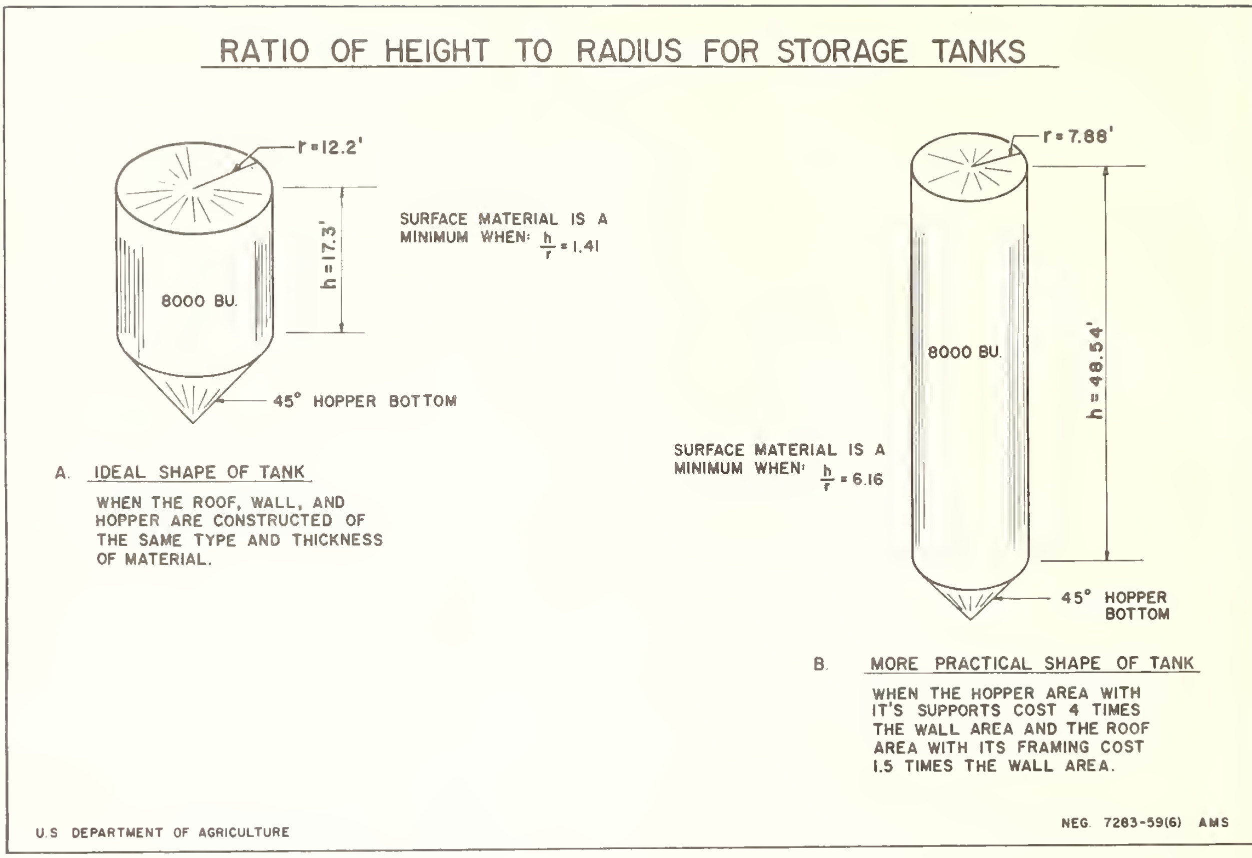

Figure 51.

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